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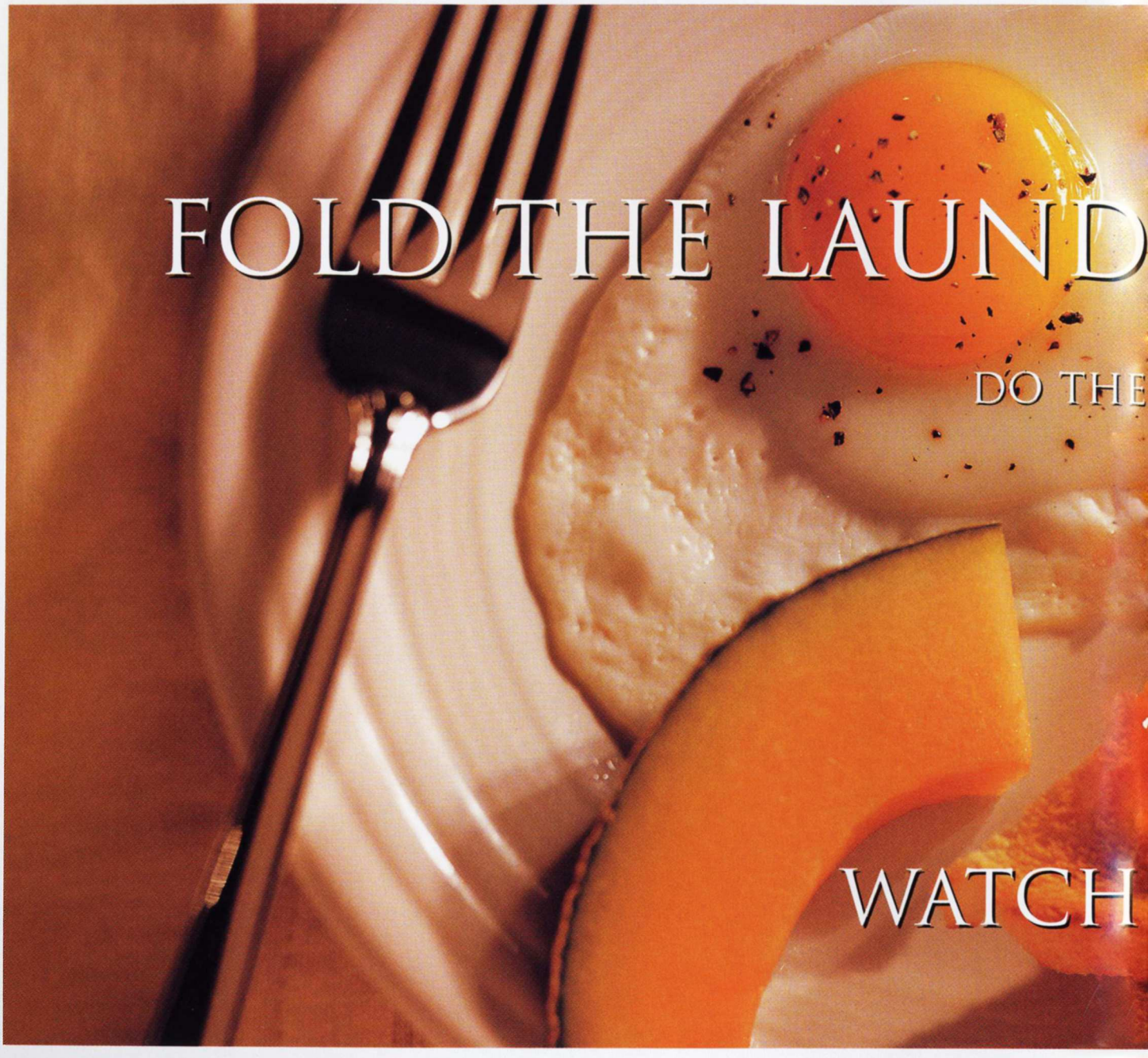

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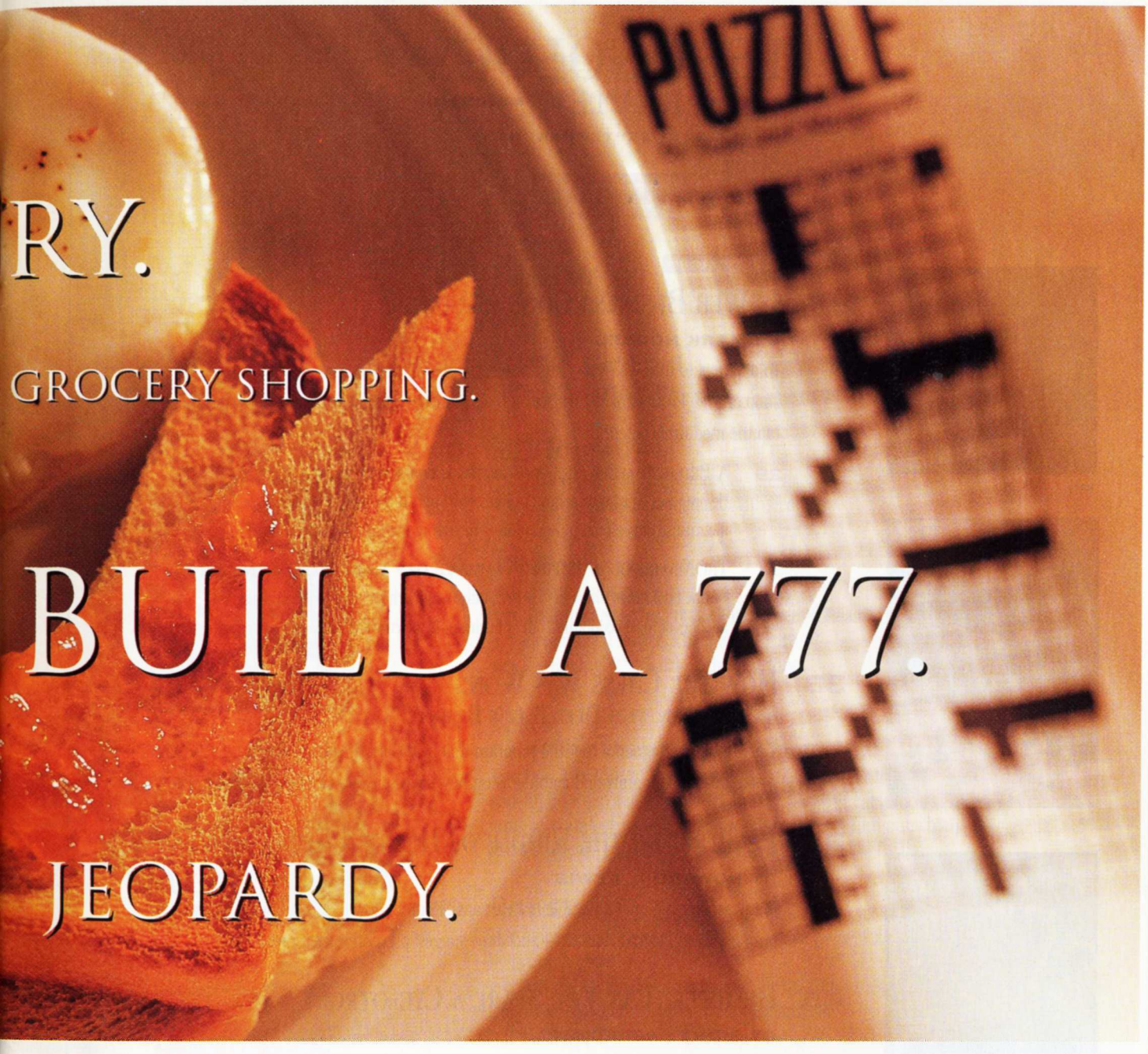

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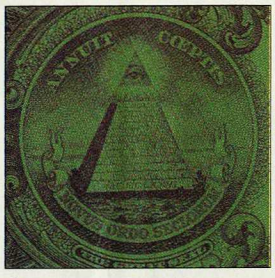
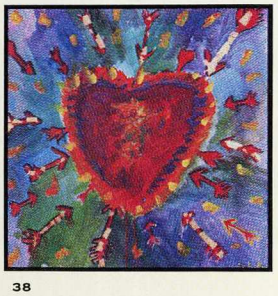
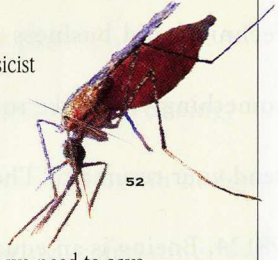


22


33


38


45


52

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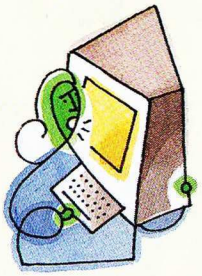
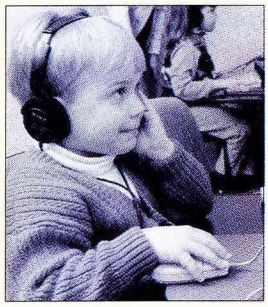
AUGUST/SEPTEMBER 1997
VOL. 100 / NO. 6


10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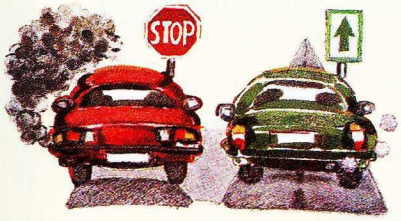
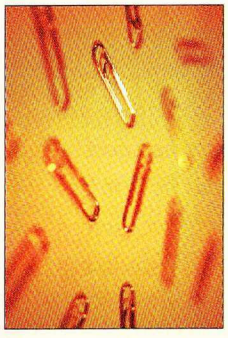


62


64

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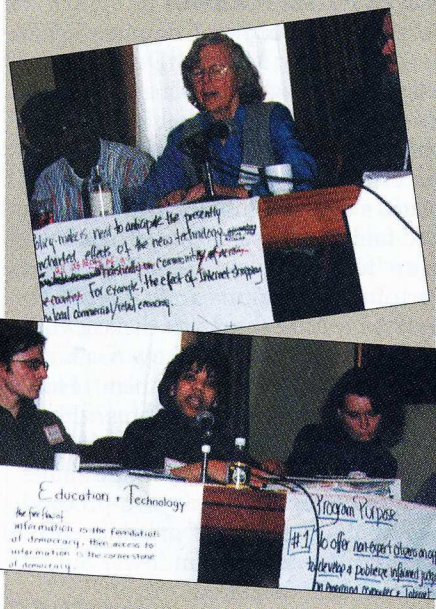


A panel of 15 everyday citizens weighs in on our technological future.

The April 4 press conference at Tufts University in Medford, Mass., was packed. Arrayed across the front of the room, the 15 members of the first-ever citizens' panel convened to focus on U.S. technology policy presented its findings to the gathered assemblage of reporters and fellow citizens.

Although the topic—"Telecommunications and the Future of Democracy"—was daunting, the panelists conducted themselves with the poise and sophistication of dedicated policy wonks. To tackle that subject, they had recently spent 50 intense hours together hashing out the profound opportunities and changes promised by the converging computer, TV, and cable industries. The springboard for this "consensus conference": an article in *Technology Review*'s July 1996 issue by Richard E. Sclove, director of the Loka Institute, a group based in Amherst, Mass., dedicated to a stronger public role in setting science policy.

In "Town Meetings on Technology," Sclove explained that Denmark pioneered the idea of providing a format for ordinary citizens to immerse themselves in a pressing technological topic and recommend courses of action. Although not intended as binding policy tools, the findings of dozens of such panels in Denmark, as well as those convened in the Netherlands and the United Kingdom, often influence government and business leaders, thanks to ensuing publicity and debate. Sclove parlayed his article, along with *TR* cosponsorship, into support for the pilot U.S. project from several sponsors, including the National Science Foundation and the Massachusetts Council on the Humanities.

A telephone campaign netted a balanced group of volunteers who spanned the spectrum from computer neophytes to afficionados but none of whom worked in the field. Once chosen, the panelists familiarized themselves with the fast-moving world of media mergers and the Internet, Web, and digital TV by reading an array of background material, including an article by *TR* senior editor Herb Brody commissioned for the occasion. The panel members then met for two weekend-long sessions to distill their thinking and home in on a list of questions they would pose to expert "witnesses" during a day-and-a-half-long public forum.

That forum, held in the wake of a freak spring snowstorm that failed to deter the participants, reflected their newfound knowledge and driving motivation: panel members wanted to know how emerging telecommunication technologies could best improve people's lives, enhance their communities, and help them participate in the political process. Queries to representatives from industry, government, academia, and nonprofit groups ranged from how to ensure the availability of low-cost, easy-to-use computers to whether revenue from the sale of the digital broadcast spectrum should help fund public TV.

After listening to the testimony, panel members retired to further refine their ideas and create a common document to present at the following day's press conference. In that report, the panel recommended that telecom businesses return a percentage of their profits to communities to help fund public Internet centers and called for stronger legislation to prevent unauthorized use of personal data files. The panel also enthusiastically endorsed the use of computers to enhance education, particularly in poor communities, but only as a tool, not a goal in itself.

As a bulletin from the Loka Institute points out (see the institute's Web site, www.amherst.edu/~loka, for the bulletin plus the text of the panel's report), the recommendations are timely because the Federal Communications Commission is now implementing many aspects of the Telecommunications Reform Act of 1996. Indeed, a co-sponsor of the pilot panel, U.S. Rep. Edward J. Markey (D-Mass.), ranking minority member of the House Telecommunications, Trade, and Consumer Protection Subcommittee (and a contributor to this issue—see "A Privacy Safety Net" on page 29), says he wants to make sure the group's recommendations are "duly considered by lawmakers."

Overall the participants, who included, among others, a retired engineer, an auto mechanic, a nurse, a manager of an inner-city computer clubhouse, an actor, and an unemployed homeless woman, professed their excitement at gaining the opportunity to weigh in on significant technological matters. "I assumed when the Telecommunications Policy Act was passed last year that it was too complicated for me to understand or influence, and that the experts knew best. I would not make that assumption now," one panelist attested.

The obvious cohesion of the diverse panel members, hard won with the help of a professional facilitator, also attested to a benefit that exceeded their growing confidence in evaluating technological change: pride in their citizenship and a renewed commitment to exercising it. All the panelists urged that similar formats be employed to build knowledge and consensus on solutions to a range of problems. To help make that happen, Sclove recently met with members of the Clinton administration to explore opportunities for replicating the process on a national level.

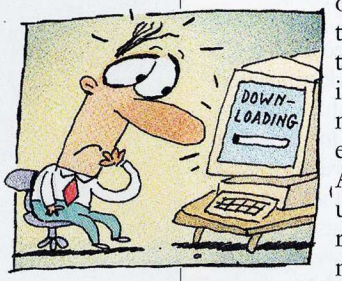
Sandra Hackman
Acting Editor

Letters

Slaves to Technology

"Creating the People's Computer" *(TR April 1997)* by Michael Dertouzos is delightful and right on. What makes this article so appealing is that it resonates with each of us in many ways.

I especially sympathize with Dertouzos's discussion of the feature overload fault. Some years ago I coined the term "feature shock," which includes Dertouzos's notion and more. To describe feature shock, let me ask you, the reader, if you know how to use all your VCR features. (Curse them!) How about your phone's features? How many blinking digital clocks do you have in your home? Can you use all the features of your favorite word-processing, spreadsheet, and graphics programs? How about Windows? Surely no one has mastered every feature of Unix!



When you purchase, for example, a word-processing program, you invest thousands of hours learning how to use it. You even feel guilty if you do not use all its features. So you learn to use more of them, raising the investment ante further. One day a more advanced word processing program hits the market. Will you switch to it? Certainly not—unless it is at least five times better than your existing package. In other words, there is natural inertia against accepting change and that is the essence of feature shock: you cannot bear the thought of giving up the features with which you have painstakingly become familiar to embark on a new and difficult feature-learning curve. Such inertia places severe restraint on the rate at which new technology penetrates the user community.

In discussing the conceptually challenged nature of software systems, Dertouzos correctly points out that humans experience constant frustration in getting machines to understand the simplest meaning of information. Many years ago, I saw the following poem taped to an early main-frame computer:

I hate this machine
I wish they would sell it.
It won't do what I want,
But just what I tell it!

We will spend much of the twenty-first century training computers to understand our meaning. Consider the alternative: the frustrating world in which we live today where we spend most of our time conforming to the archaic syntax, semantics, and interfaces of uninformed computing machines.

Leonard Kleinrock
Professor of Computer Science
UCLA
Los Angeles, Calif.

Who cannot recognize him/herself as the hapless victim of the unfriendly information technology Dertouzos describes. We owe him our gratitude for taking to task an industry that seems more interested in force feeding us than in making our lives easier and even more productive. Amusingly, and perhaps unintentionally, the article reveals the true hold information technology has on its users. There was Dertouzos, the director of MIT's Laboratory for Computer Science and the Yoda to legions of present-day software Jedi knights, "pinned against the wall [as] a meager piece of anonymous software" takes control of his PC. I wanted to shout, "Michael, use (the) Force! Control-Alt-Delete, flip the switch, or pull the plug, but don't just sit there."

William K. Nuttle
Ottawa, Ontario

In his encounter with a bewildered sales clerk, Dertouzos unintentionally provided a striking metaphor for a result of the Information Revolution: the clash between the technologically sophisticated elite, which is providing wondrous, labor-saving innovations, and ordinary citizens who have been forced to adapt.

While enabling much of the work force to execute computer tasks, information technology has simultaneously

devalued the meaningful labor of people who have spent the greater part of their careers learning and perfecting skills that have suddenly become obsolete. Postal clerks, secretaries, stenographers, and cashiers are part of the backbone of the once-solid American middle class that is being hollowed out by new technologies.

Retraining takes substantial time and often doesn't work. As many laid-off people reenter the work force in low-paying service jobs, the gap between the rich and poor widens. To offset this trend, information technology must be made readily accessible to all. While Dertouzos is to be commended for his efforts along these lines, he and other Information Age gurus need to show compassion for ordinary people who are trying their best to cope with a highly technological world.

MICHAEL RIORDAN
Soquel, Calif.

As an information systems person, I have immense respect for the author, but he is too much in the future, as are most people in the computer field. By thinking ahead about new and developing technologies, we tend to look upon what's here and now with disgust. Every technological revolution produces its share of lag time. Did Gutenberg think that changing all the letters on his printing press to create each page was tedious? Rather than complaining, he was probably excited about his invention's possibilities.

Instead of griping to readers about the airline and department-store computers that delayed him, the author should write directly to the companies involved. Both are guilty of stupidity and a lack of investment in their computers and employees.

In describing the excessive-learning fault, Dertouzos notes that a pencil does not require an 850-page manual. I challenge anyone to do with a pencil what they can do with a word processor.

Since computers themselves cannot claim to be intelligent (yet), Dertouzos is off base with the fake-intelligence fault. The beautiful people in marketing are the ones who developed the notion that computers have this attribute. Should soap detergents be lambasted for claiming that they are new and improved?

Rather than blaming his computer for downloading updates and graphics files without asking for permission, Dertouzos should dump his Internet service provider.

Sure, technology can be and eventually will be better, but we should be impressed with what we have right now.

CLARK SANDLIN
Memphis, Tenn.

I wonder if anyone else was struck by Dertouzos's obsession with time. The first four pages of the article contain 21 references that either state or imply that a faster rate of production is the ideal. I always understood that productivity refers to the making of goods and the provision of services—not to the rapid repetition of acts. Speed should not be a criterion of the good life.

ROBERT R. RODGERS
Professor of Human Development
Empire State College
State University of New York
Buffalo, N.Y.

THE ENDLESS FUSE OF TERROR

Much of the mainstream media presumed that the downing of TWA Flight 800 last July resulted from a terrorist act, some adding that it was likely done by Arabs or Muslims. "Defusing Airline Terrorism" (*TR April 1997*) by Mark Fischetti avoids the second mistake but not the first. While the article focuses on high-tech bomb detectors, it ignores actions that could prevent mechanical failure, the more likely cause of a plane crash.

Established in response to the crash of TWA Flight 800, the Gore Commission on Airline Safety and Security has also fixated inappropriately on security issues. But more egregiously, the commission has adopted passenger profiling as one of its main security recommendations. As the author correctly points out, profiling could well amount to de facto racial discrimination.

The author inaccurately portrays my experience with profiling in 1993 at the Rome airport awaiting a U.S. carrier bound for the United States. My bags were searched three times because, I believe, my previous carrier was from an Arab country, I had just come from an Arab country, and my U.S. passport indicated that I had been born in an Arab country. Sadly, my experience is not an exception. Our legal director, Houeida Saad, has documented dozens of discriminatory actions by airlines.

Passenger profiling is not only a matter of civil rights but also one of security, since people who do not fit the profile of a terrorist may go unscrutinized.

SAM HUSSEINI
Media Director
American-Arab Anti-Discrimination Committee
Washington, D.C.

While I enjoyed "Defusing Airline Terrorism," I fear that some readers will leave the article thinking that the risks of terrorism are infinitesimal and the costs of countermeasures enormous.

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Granted, terrorist activities have been extremely rare in the domestic air system, and past statistics support the claims that passengers have a "one in a billion" chance of dying on a plane and that each life saved costs millions of dollars. But considering the bombings at the World Trade Center, the Alfred P. Murrah Federal Building, and the Atlanta Olympics, can we really assume that the future risk of terrorism is minuscule? A suspected terrorist was convicted in New York City last year of plotting to blow up a dozen U.S. jets flying home from Asia. And, although the United States was long almost immune to the terrorism pervading Western Europe, terrorists have in the last decade killed twice as many Americans per capita as they have Western Europeans.

While countermeasures to terrorism are costly, we must not move too quickly to proclaim them prohibitively so. In the specific area I know best—extending the ban on unaccompanied checked baggage from international to domestic flights—the article seemed unduly pessimistic. The author quotes a spokesman as saying that the average connection time for transfer passengers at Chicago's O'Hare Airport is only 25 minutes at peak periods, thus implying that inspecting checked baggage would be impractical. But 25-minute connections are illegal for almost all the airlines serving O'Hare. A more realistic estimate of the mean is two or three times as high. The article also cited a study as suggesting that matching bags with passengers on domestic flights could cost $2 billion. That study also stated, however, that the cost could be just a fraction of that figure. As of this past spring, the airlines and the FAA were conducting tests to estimate the true cost.

ARNOLD BARNETT
Professor
Sloan School of Management
MIT

Fischetti not only examines the technical and cost issues involved in antiterrorism measures, he commendably enlarges his scope to include privacy and civil rights issues. Yet he overlooked the possible costs of any public perception that airlines, government regulators, and airport authorities cannot protect passengers—whether from terrorism or any other factor. Avoidance behaviors resulting from perception of risk are sometimes called "stigma impacts" and their costs can exceed the amount of money companies and insurers have to pay out per accident victim.

For example, in the 1982 Tylenol case, the seven deaths caused by tampering-induced poisoning cost Johnson & Johnson more than $1.4 billion in sales despite the company's swift and well-regarded response. And direct and indirect costs to the U.S. nuclear power industry from the accident at Three Mile Island have been estimated at $500 billion, even though no verifiable deaths occurred.

Instead of calculating the costs of airport screening systems in terms of passenger delays and inconvenience, a more comprehensive accounting would consider perceptions of air-travel risk and the costs and benefits (such as an increase in public confidence) of adopting new safety measures.

JAMES FLYNN
Senior Research Associate
Decision Research
Eugene, Ore.

"Defusing Airline Terrorism" was fascinating. As a frequent flyer, I appreciate some degree of effort to prevent terrorism. However, the countermeasures Fischetti described may eventually be fruitless. If we succeed at whatever cost in making it nearly impossible to place bombs on planes, then terrorists will seek alternative, if slightly less dramatic, targets, such as subways, buses, and trains. Technology is unlikely to offer solutions to such problems. The conclusion I hope our leaders draw is to emphasize attacking terrorism at its roots rather than spending excessive amounts of money and effort defending targets.

RICHARD I. MATELES
Chicago, Ill.

Continued on page 66

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MIT Reporter

Reach Out and Net Someone

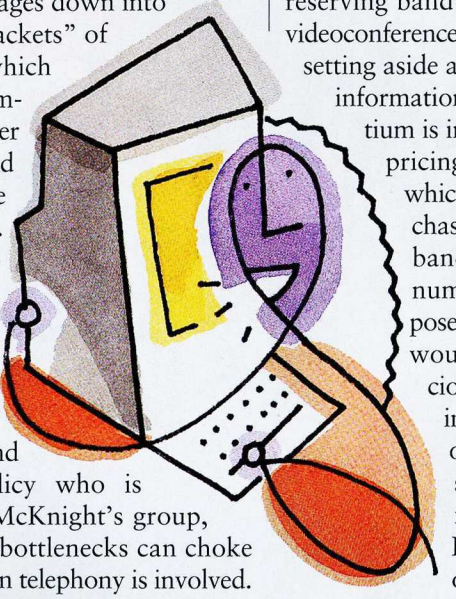
A few months ago Robert Howe, a professor of mechanical engineering at Harvard, tried to make a telephone call over the Internet. "It's not something I'm likely to repeat in the near future," he complains. "Ever experience the slight delay in an overseas call? Well, Internet telephony is 10 times worse." The sound transmission was so choppy and unreliable, he says, that both parties became frustrated. "The delays threw off the cues you normally rely on in a conversation. It was more like typing than talking."

Such problems are typical of attempts to transmit phone or videoconference communication over the Internet. Making the call is simple enough: it requires only some inexpensive software for both parties. But because digitized speech involves two to four times as many bytes per second as written text—and because voice communication is highly sensitive to even minor delays—telephony taxes the resources and current structure of the Internet.

In response to this problem, Lee McKnight, associate director of MIT's Research Program on Communications Policy, in the Center for Technology, Policy, and Industrial Development, has organized a broad, international study group to reexamine Internet protocols—the rules and procedures that govern how data are transmitted. Members of the Internet Telephony Interoperability Consortium include Sprint, U.S. Robotics, Lucent Technologies, and a number of Japanese and European telecommunications companies.

Unlike conventional telephone service, phone communication over the Internet is free to anyone with access to the Net and the right software. Interest in Internet telephony is therefore high—but so far the actual number of users is low. Though Internet telephony is "not ready for prime time," Knight says, his group is planning ahead to ensure that the Internet will be able to accommodate the demands imposed as the use of telephony increases.

The poor quality of Internet telephony is a byproduct of the way the Net transmits information. Internet protocols break messages down into manageable "packets" of information, which move from computer to computer along the Net and reassemble at the point of delivery.

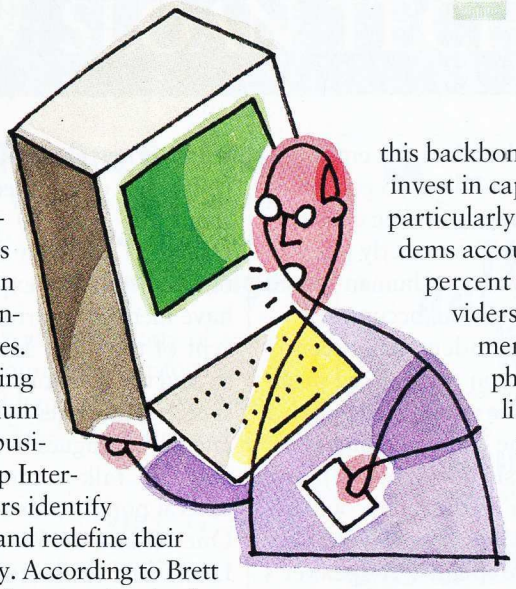


According to Andrew Sears, an MIT graduate student in electrical engineering, computer science, and technology policy who is working with McKnight's group, three potential bottlenecks can choke this process when telephony is involved. First, your own computer must digitize voice transmissions by employing data-compression software, causing delays of a few thousandths of a second. (Operating in reverse, this process is used to reassemble the message at the receiving end.) Second, if the volume of data to be transmitted overwhelms the available capacity, or bandwidth, long lines can form at each juncture as packets wait to be routed from one computer to the next. Thus hundreds of opportunities for delay can occur in a single transmission. Third, because the packets that compose a single message travel different routes to their final destination, chunks of information may become lost or delayed—taking the long way around, so to speak.

Such delays cause no more than minor inconvenience in transmitting written text, but delays in spoken communication make conversation frustrating and even unintelligible. "Right now," McKnight says, the Internet offers "no quality guarantees. That's one reason why it's so cheap to use. If it gets congested, it discards or delays information regardless of content or user preference."

One solution his group is studying is reserving bandwidth for telephone or videoconference calls—the equivalent of setting aside a high-speed lane on the information highway. The consortium is investigating a variety of pricing mechanisms through which consumers could purchase access to this reserved bandwidth. RSVP, one of numerous protocols proposed by McKnight's group, would enable e-mail aficionados to maintain their inexpensive service while other users pay extra to subscribe to voice-quality or video-quality Internet service. Other options the consortium is investigating include allowing consumers to pay a priority rate for each phone or video message or to reserve access for high-priority messages at particular times or for calls to particular

ILLUSTRATIONS: ROBIN JAREAUX



phone numbers. Even with these higher rates, Internet telephony is likely to remain cheaper than the conventional alternatives.

Students working with the consortium are developing business models to help Internet access providers identify potential markets and redefine their services accordingly. According to Brett Leida, an MIT graduate student in electrical engineering and technology policy, if telephony accounted for one-third of the time users spend online, the costs of providing Internet access would nearly double, since companies that provide the network of fibers along which information is transmitted would have to build or lease more capacity and smaller companies that provide consumers access to this backbone would have to invest in capital equipment, particularly modems. (Modems account for about 70 percent of small providers' capital investment. Because telephony users are likely to dial in more frequently or stay online for longer periods than other users, explains Leida, companies that provide Internet access to dial-in users will need to invest in additional modems to handle the incoming data stream.)

Many smaller providers, Leida says, are concerned about the potential cost burden because it is difficult to raise rates in this competitive market. One potential strategy is to shift their customer base from dial-in users (households and small offices) to larger businesses with whom they can maintain direct network ties, precluding the need to invest in modems.

Apprehension over these growing costs has also fueled the interest of providers in user-differentiated pricing, Leida notes. Offering a less expensive rate to users who make Internet phone calls only during certain hours could smooth out peaks in demand, offsetting the pressure to invest in additional modems.

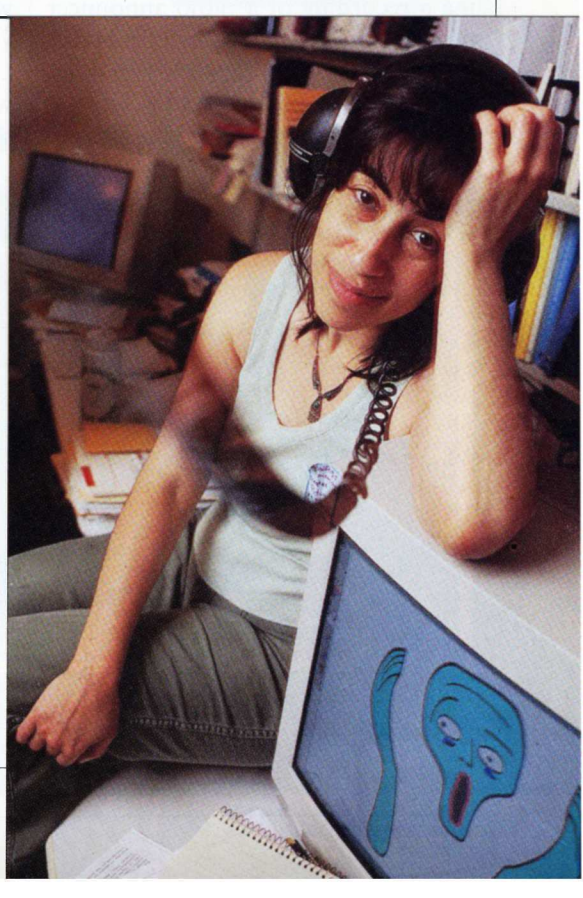
McKnight's group also plans to address policy questions such as the role of the Federal Communications Commission in regulating Internet telephony, and the potential for offering universal access to Internet telephony as an alternative to conventional telephone service. "Telephony places many new demands on the Internet," he notes. "We want to be ready with suggestions and models to prepare the way."

—*Robert J. Crawford*

Saying It with Feeling

At the Boston Computer Museum, next to a machine that guesses one's height, sits an inconspicuous display consisting of a simple computer terminal. The exhibit, called "Synthetic Emotional Speech," is intended more for the ears than for the eyes. The computer recites lines from the play *Waiting for Godot* and the Abbott and Costello routine "Who's on First?" using any of six emotions the user specifies: annoyed, cordial, disdainful, distraught, impatient, or plaintive.

The idea of putting some feeling into computer-generated speech is part of an effort by Janet Cahn, a graduate student in the MIT Media Lab, to make such speech "come alive," she says. Her principal motivation is to develop software that can help speech-impaired people communicate more effectively. "Most nonspeaking people are frustrated by the technical options currently available to them," she says. "They don't want to talk like a machine," especially since emotions help convey a sense of the speaker's mental state. Cahn adds that more authentic-sounding synthetic speech might lead to better computerized reading devices for blind people, emergency telephone systems that could provide information to callers in a calm, soothing voice, and even playback units that screenwriters might use to test dramatic dialogue.



Despite what the icon suggests, the expressive speech Janet Cahn's software is generating doesn't seem to bother her.

PHOTO: MARK OSTOW

The display at the Computer Museum is based on a program Cahn wrote called "Affect Editor" that alters the speech emitted by DECtalk, a standard synthesizer. When a user selects an emotion for the reading, the software assigns one of 21 integers (from -10 to 10) to each of numerous acoustical qualities representing aspects of pitch, voice quality, timing, articulation, and loudness. The program specifies that angry speech, for instance, is loud, high-pitched, quick, and characterized by irregular rhythms, inflections, and precise enunciation. Sad speech is soft, low-pitched, and slurred, displaying minimal variability and many pauses.

To create this software, Cahn drew on previous research that had determined acoustical qualities characteristic of various emotions. In the late 1960s, for example, investigators isolated features of fearful speech by conducting analyses of pilots' voices just before their planes crashed. A 1972 study explored acoustical aspects of anguish by examining a recording of a radio announcer reporting the crash of the Hindenburg.

After incorporating such variables, Cahn fine-tuned the model by testing it on a small group of people. The 28 subjects correctly identified the emotions conveyed by Affect Editor 53 percent of the time—a promising finding considering that the subjects correctly guessed the emotional content of human speech with only slightly greater accuracy.

The doctoral student has recently turned her attention to a related problem: developing for synthesized speech a sense of what she calls speaking style. "A classical music host, rock DJ, and sports announcer on the radio could use almost identical words yet sound very different," she explains. A speaker's style can range from formal to informal, varying according to the audience and subject matter.

Relying on research findings similar to those she used to create Affect Editor, Cahn is creating software that can alter style by modifying rhythm, stress, and other variables that also contribute to the emotional aspects of speech. The style program is "definitely not ready for primetime," she says. "But both emotional content and style are essential if we're going to reproduce the range and variability of human speech."

Cahn is one of a handful of researchers working in the area of natural-sounding synthetic speech. Across the Atlantic, Iain Murray, a computer scientist at the University of Dundee in Scotland, has spent the past 10 years developing HAMLET, software that produces emotional speech that experimental subjects have identified correctly about 50 percent of the time. Murray has demonstrated the potential range of a standard speech synthesizer by making it sing: he and his colleagues have used HAMLET and DECtalk to create the vocals for several pop records released in Britain. One album, a 1989 recording by the Love Child Orchestra, even cracked the Top 100.

Cahn anticipates several more years of research before developing practical, commercial applications. After completing linguistic research, the results will need translating into fast and flexible computer systems. Testing on larger groups will be necessary, as will meetings with groups of potential users.

The task is demanding, she says, because the choices people make regarding speech are so complex: "We have so many different ways of expressing ourselves."

—*STEVE NADIS*

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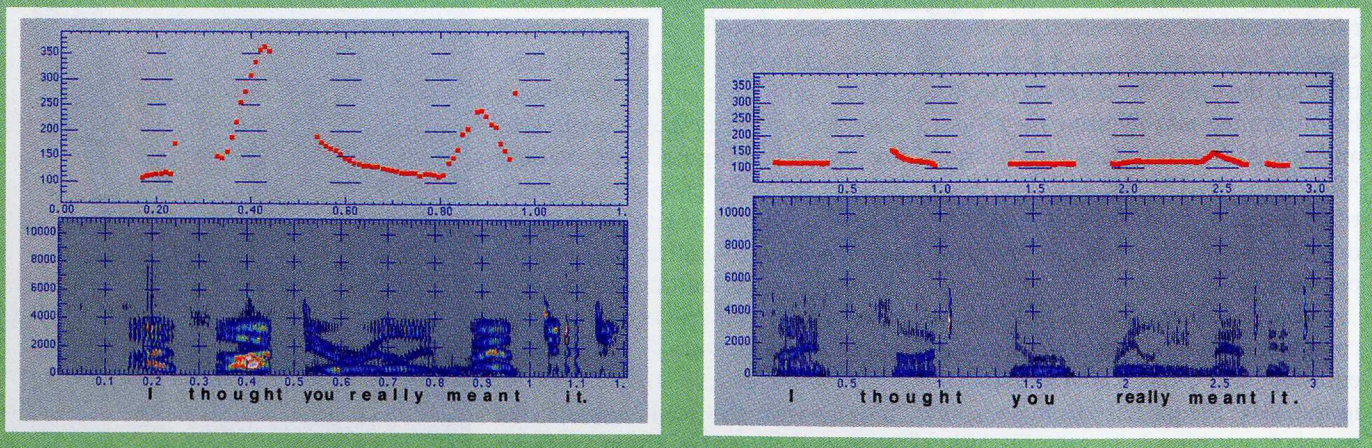


Cahn's software enables a computer to utter a line such as "I thought you really meant it" using different emotional styles. Speech that is annoyed (left) varies in pitch (top) and frequency strength (bottom) from speech that is sad (right).

ILLUSTRATION: JANET CAHN

Trends

A New Light on Cancer

When John Graham's throat cancer returned a year and a half after it was seemingly eradicated by standard radiation therapy, his doctors thought the best option for the Minneapolis salesman would be a laryngectomy—an operation that would leave him with half a voicebox. Before consenting to the radical procedure, however, Graham (not his real name) sought a second opinion from Merrill Biel, an oncologist at the Abbot-Northwestern Hospital in Minneapolis, who had reported success with an innovative cancer treatment called photodynamic therapy (PDT).

Instead of performing surgery, Biel proposed to inject Graham with an experimental photosensitive drug, Photofrin, which attaches to special proteins in the blood that accumulate in abnormal tissues such as tumor cells. (The drug also gathers to some extent in healthy tissue, though in much lower concentrations.) Two days after the injection, Biel explained, he would thread a laser-tipped tube through Graham's throat and bathe the affected area in laser light. The light would activate the Photofrin—a synthetic version of natural, light-sensitive agents called porphyrins—which would, in turn, release toxic agents that kill cancer cells.

One of the main advantages of PDT is that Photofrin has no toxicity unless light is shined on it. Chemotherapy drugs, by contrast, are poisonous to cancerous and healthy cells alike, though they, too, can save lives. Another benefit is that PDT, unlike radiation therapy, can be repeated as often as necessary without danger to the surrounding healthy tissue, so long as the light beam is focused squarely on the tumor. And PDT is less draconian than surgery, the other cancer stalwart. "If PDT doesn't work, you can always do surgery," Biel explains. "But if you take the voicebox out, you can't put it back in."

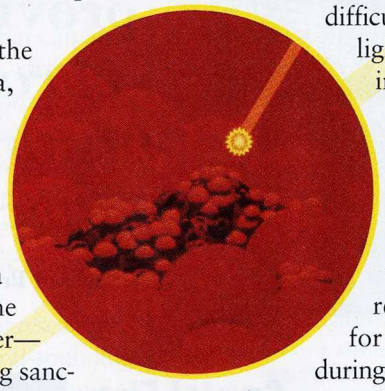
Graham opted for the experimental therapy. And the decision appears to have paid off. More than five years later, Graham remains cancer-free. In fact, so have most of Biel's other patients: of some 120 patients with vocal-cord and mouth cancer that he has treated with PDT over the past eight years, 95 percent are apparently cured.

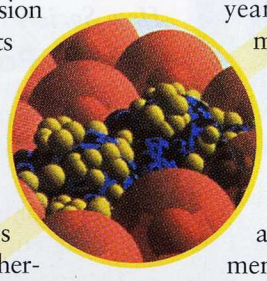
Other researchers in the United States, Canada, Japan, Europe, and Australia have reported similarly encouraging findings. As a result, PDT is finally getting some official recognition. In 1993, Canada approved Photofrin for the treatment of bladder cancer—the first light-activated drug sanctioned for use anywhere in the world. A year later, the drug received marketing approval in Japan and the Netherlands for treating early-stage lung, esophageal, and other cancers. The U.S. Food and Drug Administration approved the drug for treatment of esophageal cancer in 1995, and French health regulators granted a similar endorsement in 1996.

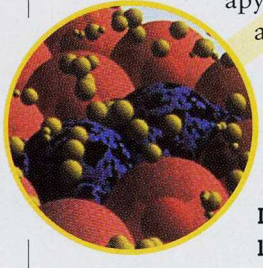
This progress stems largely from the efforts of Thomas Dougherty, who created Photofrin and has promoted PDT since the early 1970s. "For the longest time, hardly anyone was interested in Photofrin," says Dougherty, head of radiation biology at the Roswell Park Cancer Institute in Buffalo. "We managed to change people's minds not by what we said, but by making the drug available to other investigators whose clinical findings speak for themselves."

The technique does have limitations, however. "Once you've found the tumor, the big question is how to get the light there," says Thomas DeLaney, chief of radiation oncology at Boston Medical Center. Indeed, while some internal organs can be reached using flexible fiber optic catheters, the approach is unable to destroy very large tumors because of the practical difficulties of distributing light throughout the interior of a sizable mass. What's more, PDT's greatest strength, its photosensitivity, is also its greatest weakness. Photofrin is retained in the skin for about six weeks, during which time patients have to avoid direct sunlight or bright lights to prevent the possibility of inadvertently damaging or killing normal cells.

The good news is that some half-dozen companies, including Quadra Logic Technologies (QLT), the Vancouver, British Columbia, company that is marketing Photofrin, and PDT, Inc., in Santa Barbara, Calif., are developing second-generation drugs to avoid these problems. QLT's new light-sensitive compound, benzoporphyrin derivative (BPD), leaves the body much more quickly, so a patient has to remain out of the sun for only a couple of days. Some



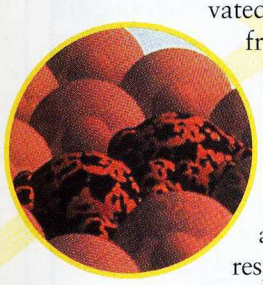




In an innovative cancer therapy (left to right, above), a photosensitive drug (green dots) accumulates in rapidly proliferating cells (blue) and then, when exposed to laser light (red), releases toxic agents, killing malignant tumors.

ILLUSTRATIONS: QLT PHOTOTHERAPEUTICS

researchers believe the drug will be able to attack larger and deeper tumors than Photofrin because it is activated by lower-frequency light that penetrates farther into human tissue.



Progress on the pharmaceutical front has been accompanied by corresponding advances in light-delivery technology. "In the early days, we used big, expensive lasers that had to be operated by a trained technician," says Dan Doiron, chief scientist for PDT, Inc. "We now have cheaper, more compact laser systems that can be operated by doctors and nurses in a small hospital or office setting." These laser and pharmaceutical advances "open up opportunities for treating a wide range of diseases in addition to cancer," he notes, because PDT drugs selectively congregate in a variety of rapidly growing cells, not just cancerous ones.

Investigators are therefore exploring applications for treating such disorders as eye diseases, psoriasis, and rheumatoid arthritis. QLT, for instance, is testing the drug BPD for the treatment of age-related macular degeneration—the leading cause of blindness in people over the age of 50. BPD accumulates in the network of abnormal blood vessels in the eye that obscure vision; when illuminated with laser light, the compound can clear away those unwanted vessels. BPD also tends to accumulate in greater concentrations in the rapidly proliferating skin cells characteristic of psoriasis, which, too, can be destroyed by the administration of light. In preclinical trials, treatment with BPD and light also selectively killed cells that proliferate in the joints of patients suffering from rheumatoid arthritis. And more recent clinical trials have shown that the drug can suppress the activation of immune cells that cause the symptoms of psoriatic arthritis.

Although conventional cancer therapies will still be needed to treat tumors that cannot be illuminated by optical means, as well as malignancies that have spread throughout the body, PDT can complement existing techniques. Biel predicts PDT will take its place alongside surgery, radiation, and chemotherapy as a fourth weapon in the anticancer arsenal. And patients who have exhausted the usual options may have another chance. —*STEVE NADIS*

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Training Dyslexics First to Hear, Then to Read

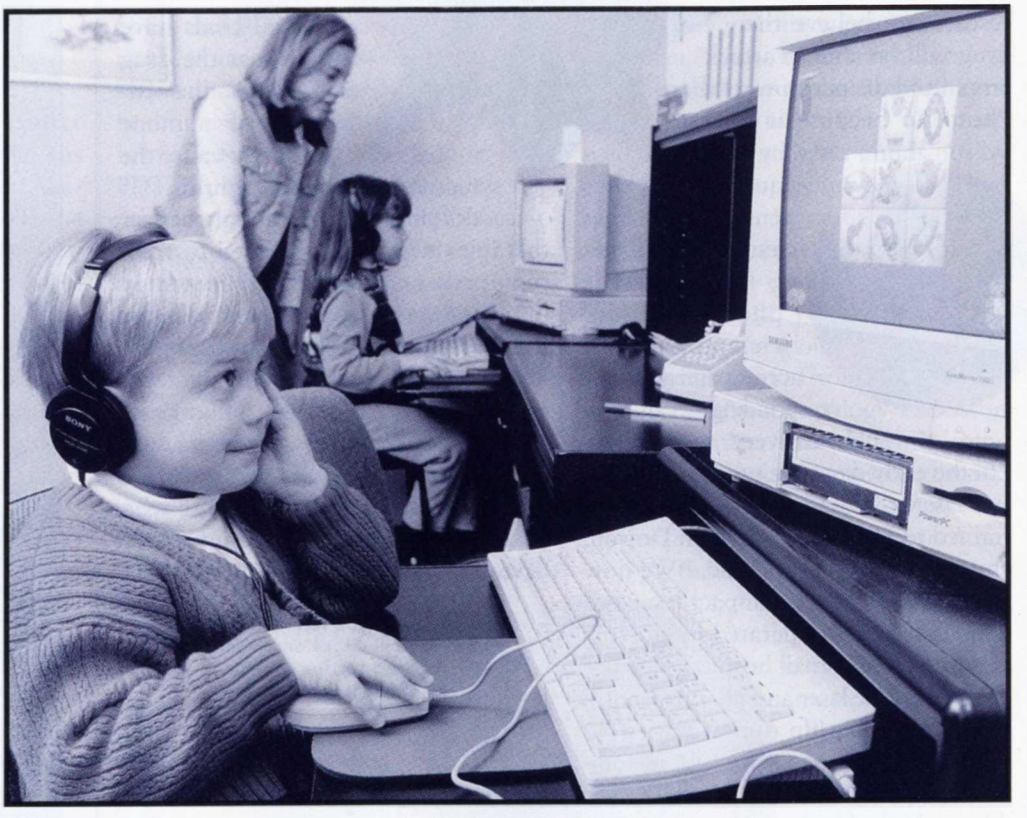
For most of us, reading comes as naturally as falling off a log. But for many otherwise normal—and even gifted—individuals, the task is an arduous one. In fact, as many as one in five schoolchildren suffers from dyslexia, an unusual difficulty in reading.

Scientists theorize that although dyslexic children can hear normally, they can't accurately interpret many language sounds and, therefore, can't remember which symbols represent which sounds. This deficiency causes problems in both spelling (translating from sounds to symbols) and in reading (translating from symbols to sounds).

Now speech researchers Paula Tallal of Rutgers University and Michael Merzenich of the University of California at San Francisco have devised a novel computer program that addresses what they believe is the underlying cause of the

deficiency: an inability to identify the correct sequence of acoustic cues that indicate language sounds, cues which in normal speech are presented so compactly that they overlap with each other.

Tallal bases her conclusions on 20 years of research on six- to nine-year-old children. In one study, she asked dyslexic subjects and normal readers of the same ages to listen to two complex tones of different pitches. She then asked both groups to repeat the order of the tones, using computer keys. As the time period between the tones became shorter, the performance of the dyslexic children deteriorated rapidly, while that of the normal readers was not affected. Normal readers reached the target score, 20 correct responses out of 24, with intervals as short as 8 milliseconds, but dyslexic readers needed at least 305 milliseconds to achieve the same score. When she repeated the experiments using three, four, and five tones, the differences in performance were virtually the same.



A novel computer game that plays back speech at half speed and makes certain sounds more distinguishable helps dyslexic children overcome the root cause of their reading deficit—an inability to correctly interpret language sounds and assign them the correct symbols.

Tallal also asked the children to indicate whether the pair of tones they heard were the same or different. She found, similarly, that impaired subjects, unlike those who could read normally, could not differentiate among the tones at rapid rates of presentation. But their performance improved dramatically when she lengthened the duration of the tones and the spacing between them.

Tallal reasoned that slowing down speech sounds in the same way might help dyslexic subjects sort overlapping cues into discrete events—the task entailed in understanding language. So she processed normal recorded speech to make it 50 percent slower and boosted the volume of the transitions from consonants to vowels to make them more prominent. Played back, the processed speech resembles what a slightly testy computer might sound like: condescendingly slow and faintly metallic. To make the processed speech appealing to children, Tallal and Merzenich incorporated it into a computer game in which kids try to identify certain sounds and gradually work their way up from slow to normal speech.

Tallal and Merzenich—who have formed a company, Scientific Learning, to market the game—are encouraged by the kids' reaction. Tallal reports that reading-disabled kids show a keen interest in the processed speech that their normal counterparts don't. More important, though preliminary, are the results: One group of seven children aged five to ten years began the program two to three years behind their peers in language development. After four weeks of intensive training, six of the seven improved their language-comprehension skills to near-normal, normal, or above-normal levels. Another group of eleven children yielded ten success stories after similar training.

Other speech researchers, including Michael Studdert-Kennedy of the Haskins Speech Laboratories in New Haven, Conn., and Maria Mody of the Albert Einstein College of Medicine in New York, agree that dyslexia is often, if not always, associated with a phonological deficit. But in their view, it is an impoverished ability to differentiate among

PHOTO: SCIENTIFIC LEARNING CORP.

similar-*sounding* speech sounds that causes dyslexics to make errors—not a difficulty ordering speech sounds.

To show that impaired readers have difficulty distinguishing only among similar language sounds, as opposed to those that are distinctly different, Mody tested a group of 20 second-grade children selected expressly for their errors on one of Tallal's tests. When she asked children to report the order of syllables "ba" and "da," they made more errors when the syllables were presented closer together. But when the syllables they heard were not as similar, such as "ba"-"sa" or "da"-"sha," the children made almost no errors on either task.

Tallal and Merzenich say the success of their program in helping kids learn to read argues for the validity of their approach. But they concede that more research is necessary to understand why impaired readers have trouble distinguishing among some sounds but not others. They also point out that it is still unclear why dyslexic readers err when trying to sort language sounds into the correct sequence of letters. One possibility is that because they find it much harder to tell the difference between speech sounds, they simply need more time to make decisions about them, and this leaves little attention left over to remember the sounds' exact order. It's like the "I Love Lucy" episode where Lucy and Ethel are struggling to inspect chocolates passing them on a conveyer belt. After a while they give up trying to select the right ones and simply grab whatever happens to be in front of them at the time. —*KAREN CHENAUSKY*

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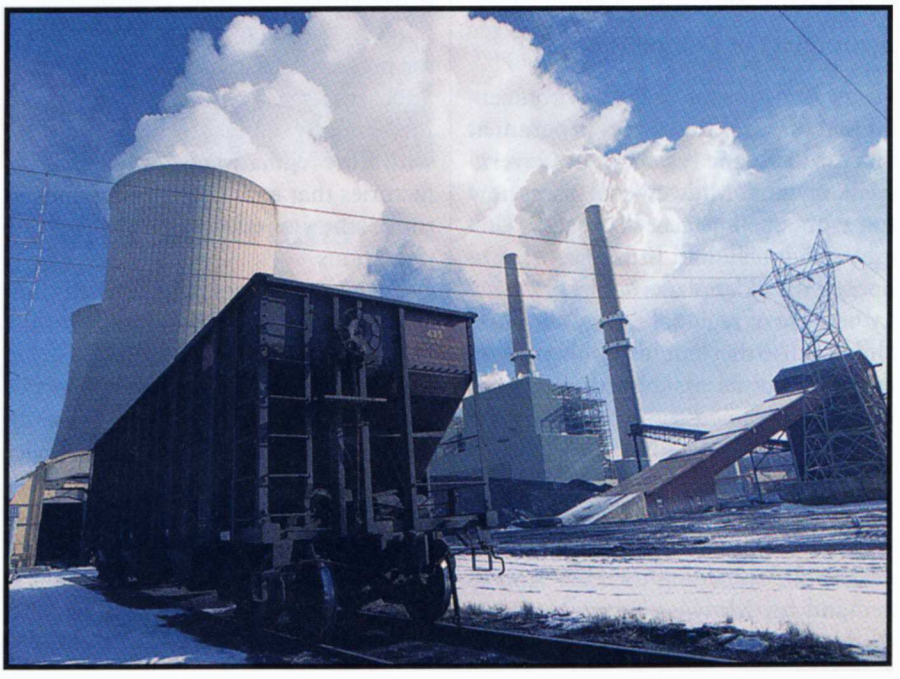
Deregulated Power: Cheaper but Dirtier?

The Paradise, Ky., electric power plant is no heaven on earth, at least in terms of its propensity for polluting the air. In fact, its coal-fired boilers are among the nation's dirtiest, spewing noxious nitrogen oxides into the atmosphere at the rate of some 135,000 tons per year, according to data reported by the utility to the Environmental Protection Agency.

Unfortunately, operations at Paradise, built in 1963 and operated by the Tennessee Valley Authority, and similar coal-burning plants are not likely to shut down or even scale back any time soon. In fact, since the Federal Energy Regulatory Commission (FERC) implemented its so-called "open access" rule last year allowing utilities to compete with one another by selling power directly to customers, the danger exists that coal plants will operate at higher capacity, according to the EPA, and create even more pollution.

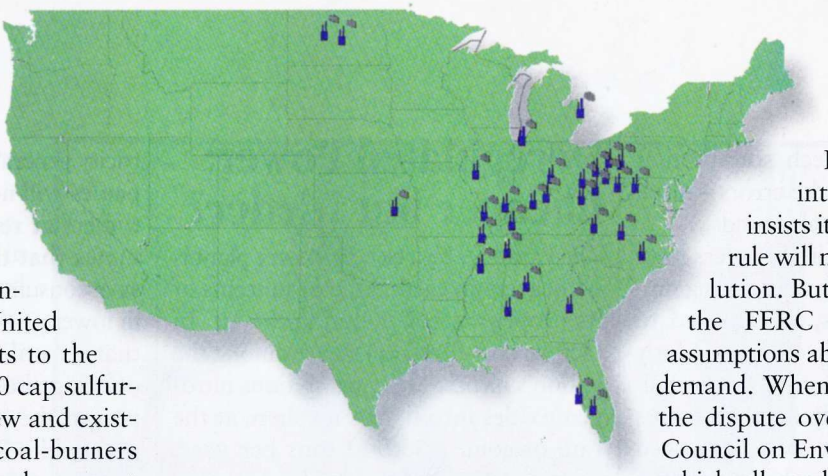
As states and the federal government break century-old monopolies over electricity generation and sales, power companies will no longer serve captive customers at regulated rates. FERC estimates that the open competition will save consumers some $5.4 billion a year in lower power bills. But the EPA warns that as utilities strive to compete by offering the lowest prices for electric power, they will expand operations at plants like Paradise and its coal-fired cousins, which are less expensive to operate because of low fuel costs and fewer investments in pollution-control equipment, but are dirtier than newer plants fired by natural gas. Some of the chemical contaminants produced by these coal-burners—which reside largely in the Midwest's Ohio River Valley—will drift eastward on prevailing winds, settling on Mid-Atlantic and New England states, which are already struggling to reduce emissions.

Even before the new competitive climate, the electric-utility industry has been the biggest source of air pollution, exceeding motor vehicles in most cases. EPA figures show that power generators are responsible for 66 percent of all sul-



Deregulated electric power—designed to lower prices for consumers by heightening competition among utilities—may spur greater use of cheaper-to-operate but more-polluting coal-burning plants.

PHOTO: AP PHOTO/GEORGE WIDMAN



Emissions from the most-polluting coal-fired plants (above) drift eastward and settle on Mid-Atlantic and New England states.

fur-dioxide emissions, 29 percent of all nitrogen-oxide releases, 21 percent of airborne mercury, and 36 percent of all carbon-dioxide emissions in the United States. While amendments to the U.S. Clean Air Act of 1970 cap sulfur-dioxide releases in both new and existing plants, hundreds of coal-burners built before 1970 are largely exempt from other environmental controls, including limits on nitrogen oxides. Moreover, some pollution that the plants release—such as mercury—remains totally unregulated.

These pollutants have adverse effects on human health and the natural environment. For example, nitrogen oxides, along with sulfur dioxide, combine with sunlight and other compounds to form ozone, the prime component of "smog" that damages lungs and stunts plant growth. Nitrogen oxides are also a chemical precursor of acid rain, which has harmed lakes, streams, and forests in the Northeast. And mercury is toxic to humans and animals alike.

Byproducts of Competition

Henry Lee, director of the Environmental and Natural Resources program at Harvard's Kennedy School of Government, says that Midwest coal plants now run at about 64 percent of capacity. Utilities previously had little incentive to operate the older plants at higher capacity because of regional energy surpluses and because they could simply pass on the added costs associated with their newer plants to customers. But as competition to offer the lowest prices heats up, utilities may run their coal-burners more. At the same time, consumer demand for power will likely rise if prices fall, according to Lee. "And as demand for Midwest power goes up, there's a trade-off," he says. "You can build new gas plants or you can utilize the coal plants more; my guess is it will probably be more of the latter."

Lee estimates that even an annual 3 percent increase in the production of coal-based electricity by the year 2000—a likely scenario, he believes—would send nearly 500,000 more tons of nitrogen oxides into the atmosphere per year, or about an 8.2 percent increase over the rise in nitrogen oxide expected without competition. And emissions of carbon dioxide, the prime "greenhouse" gas blamed for global warming, he says, would rise by 43 million tons per year, or 7.8 percent over the projected rate without competition. Such increases could be enough to throw many states out of compliance with EPA regulations and likely cause factories that emit these compounds in those states to cut back or shut down operations.

Other researchers have reached similar conclusions. In a recent study for the EPA, the ICF Kaiser Consulting Group of Fairfax, Va., looked at the impact of electric competition on air pollution. The ICF study reports that as electricity prices fall, demand will rise, and power companies will crank out more electricity, leading to 362,000 tons more nitrogen oxide pollution from a 95.6 billion kilowatt hour boost from coal plants in the year 2000.

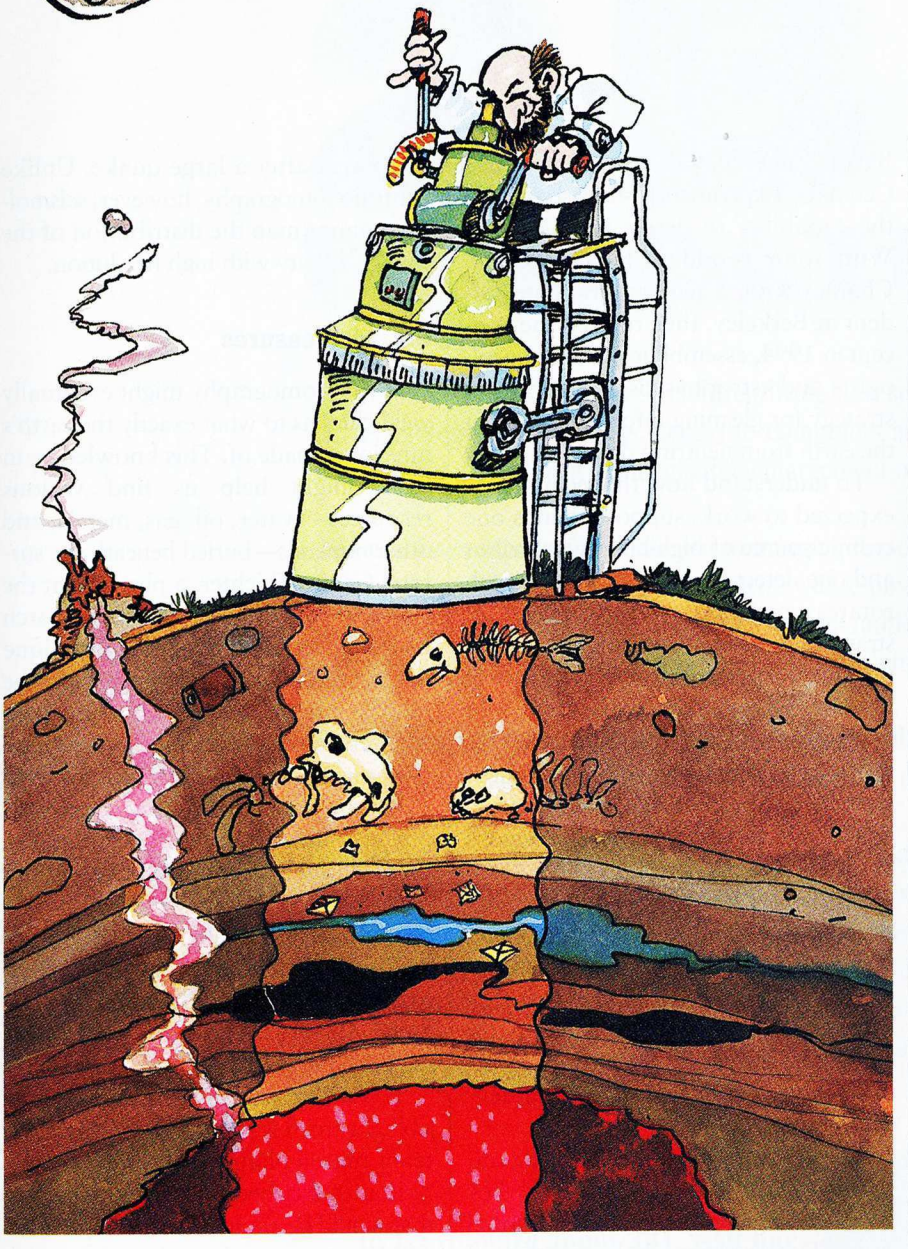
FERC, which governs interstate power deals, insists its 1996 "open access" rule will not cause more air pollution. But the EPA claims that the FERC model uses faulty assumptions about power prices and demand. When the agencies turned the dispute over to the President's Council on Environmental Quality, which allowed FERC to move forward with competition, the council decided that the EPA's concerns "deserve serious consideration" and that further air-quality regulation may be needed.

Meanwhile, some eastern states are tackling the problem by adopting pollution standards as part of their deregulation plans. Vermont's proposed plan, for example, would require that companies selling power to the state hold emissions to 1996 levels. Regulators also hope that informed consumers will opt to buy power that is less polluting. Toward that end, Massachusetts, Rhode Island, and Vermont have all endorsed a plan to provide information on environmental emissions to customers.

But air pollution does not honor state boundaries, and the EPA is considering a national approach that uses market forces to control air emissions. The agency may try to establish a "cap and trade" program whereby the government would set an overall limit on the amount of nitrogen oxide that the utility sector is allowed to emit, and then allow plants to buy or sell pollution credits. The cap would be set nationally but also could be parceled out by region, or possibly by states. A cleaner power producer could then trade or sell its pollution allowance to a dirtier generator. A similar system is used by power companies under the Clean Air Act of 1990 to limit sulfur-dioxide emissions nationwide.

—*JOHN A. DILLON*

ILLUSTRATION: OFFICE OF SEN. PATRICK LEAHY



"X-Raying" the Earth with Neutrinos

Imagine astronomers gazing up one end of a telescope, trying to create pictures of the sky, while geologists peer down the other end, looking through a kind of microscope that can penetrate the earth's innermost sanctums. Sound improbable? Well, welcome to the wacky world of neutrino astronomy, where down is up and up is down and occasionally the twain do meet.

Astronomers have been laying traps for high-energy neutrinos in some of the more remote spots on the planet: far beneath the Mediterranean Sea, in Siberia's Lake Baikal, and deep in the ice caps of the South Pole *(see "Hunting the Wild Neutrino," TR April 1997)*. They hope that these elusive particles—with little or no mass and no electric charge—will reveal secrets about the violent places in deep space from which they came: black holes, quasars, and pulsars.

Now, however, geologists are hoping to use the neutrinos snared by these detectors to see if they can learn something about the earth's constitution. Despite their infinitesimal size and fleetness (bounding at or near the speed of light), some of these neutrinos will be stopped in their tracks as they crash into atoms inside the earth. The denser the region, the greater the likelihood that it will block a neutrino. By keeping track of how many neutrinos reach the detectors as they travel through the earth, scientists can calculate where they were absorbed and in what quantities to obtain a picture of the planet's "internal density structure."

Detecting Dense Regions

Medical computer tomography (CT) employs a similar approach. Machines record the transmission and absorption of x-rays as they criss-cross through the human body, allowing observers to detect tumors or other masses. "We want to do the same thing with the earth, using neutrinos instead of x-rays," explains Raymond Jeanloz, a geologist at the University of California at Berkeley.

Neutrino tomography was first proposed in the late 1970s by two physicists, John Learned at the University of Hawaii and Hugh Bradner at the Scripps Institution in San Diego. The duo realized that neutrinos—produced as a byproduct of the reactions occurring at the heart of every star—abound in the universe. But they set the idea aside because there were no available means of capturing the high-energy particles as they reached—and passed through—the earth.

Now, new observatories under development—including AMANDA (the Antarctic Muon and Neutrino Detector Array), NESTOR (named after the famous Greek king) off the coast of Greece, the Neutrino Telescope in Lake

ILLUSTRATION: JON McINTOSH

Baikal, and RICE (the Radio Ice Cerenkov Experiment)—may soon have the capability to detect the particles. With some prodding from Learned, Chaincy Kuo, a geology graduate student at Berkeley, thus revived the concept in 1994, assembling a team of geologists and astrophysicists to develop a strategy for gleaning information about the earth from neutrino data.

To understand how the technique is expected to work, suppose there's one cosmic source of high-energy neutrinos and one detector on earth. As the earth rotates, neutrinos, which travel in straight lines, would cut different swaths through the planet en route to the detector. Observers could note the number of neutrinos detected for each separate route and determine where the most were being absorbed. That information would indicate where the densest regions of the earth were.

In reality, there would be many sources and many detectors. In time, therefore, neutrino absorption could be measured along a web of lines that slice through the entire planet. A computer could then combine these measurements to produce a composite image of density variations.

Density variations are significant, according to Jeanloz, because "they drive geologic processes on a global scale." Denser regions in the mantle tend to sink, whereas less dense materials tend to rise. This continual subterranean churn gives rise to the movement of tectonic plates as well as to earthquakes and volcanoes.

Estimates of the earth's density now rely primarily on seismological techniques. After an earthquake, scientists can measure the velocity of seismic waves that travel through the ground to a network of sensors—the denser the material, the faster the waves move. Additional information comes from studying the vibrations (or ringing) of the planet after a large quake. Unlike neutrino tomography, however, seismology cannot map the distribution of the earth's density with high resolution.

Buried Treasures

Neutrino tomography might eventually yield clues as to what exactly the earth's interior is made of. This knowledge, in turn, might help us find various resources—water, oil, gas, metals, and other minerals—buried beneath the surface. George Frichter, a physicist at the University of Delaware's Bartol Research Institute, suggests that the technique might even tell us something about the moon's interior if we observe how neutrino measurements change as the moon passes in front of the earth detector.

But the viability of neutrino tomography still hinges on one question: Are there enough detectable high-energy neutrinos for this to work? Hawaii's Learned has no doubt that high-energy neutrinos are abundant and are waiting to be nabbed. "But how many are out there? And are the detectors we're building big enough?"

To capture as many neutrinos as possible, Learned is part of an international team that is planning to build a giant "kilometer-cubed" neutrino telescope that would be about 50 times larger than the latest generation of instruments. Construction could begin within 5 to 10 years, possibly at the NESTOR site in the Mediterranean. "Given its size," Learned says, "this device should have a real ability to do earth tomography—not just gross density measurements, but high-resolution scans."

Such a massive detector would not come cheap, costing $100-200 million. On the plus side, Learned says, the neutrino beam itself is free, produced by "cosmic accelerators that are not subject to the whims of political agencies."

— *STEVE NADIS*

2B1 FOUNDATION

For some tens of millions of children living in a small number of technology-rich countries, access to computers and the Internet has brought a previously unimaginable enlargement of perspective.

2B1 is a new organization dedicated to bringing these benefits to the other billion children who live in countries where poverty, geographical isolation, or closed political regimes make it unlikely that any but a privileged few will be touched by the digital revolution.

But 2B1 is about far more than what the world should give to its children. It is ultimately about what children can give to the world.

The founders of 2B1, which has been set up as an independent not-for-profit organization, include MIT professors Nicholas Negroponte and Seymour Papert, who bring a close link to the Media Lab's programs of research on digital life and learning. Central to these programs is the idea that digital technology can empower children to take a more active role in shaping their own futures and the future of the world they live in.

To Learn more about 2B1, visit our web site at www.2B1.org

If you sympathize with its plans and want to know how to participate, announce yourself by email to: helpers@2B1.org or send a fax to: (617) 253-6215

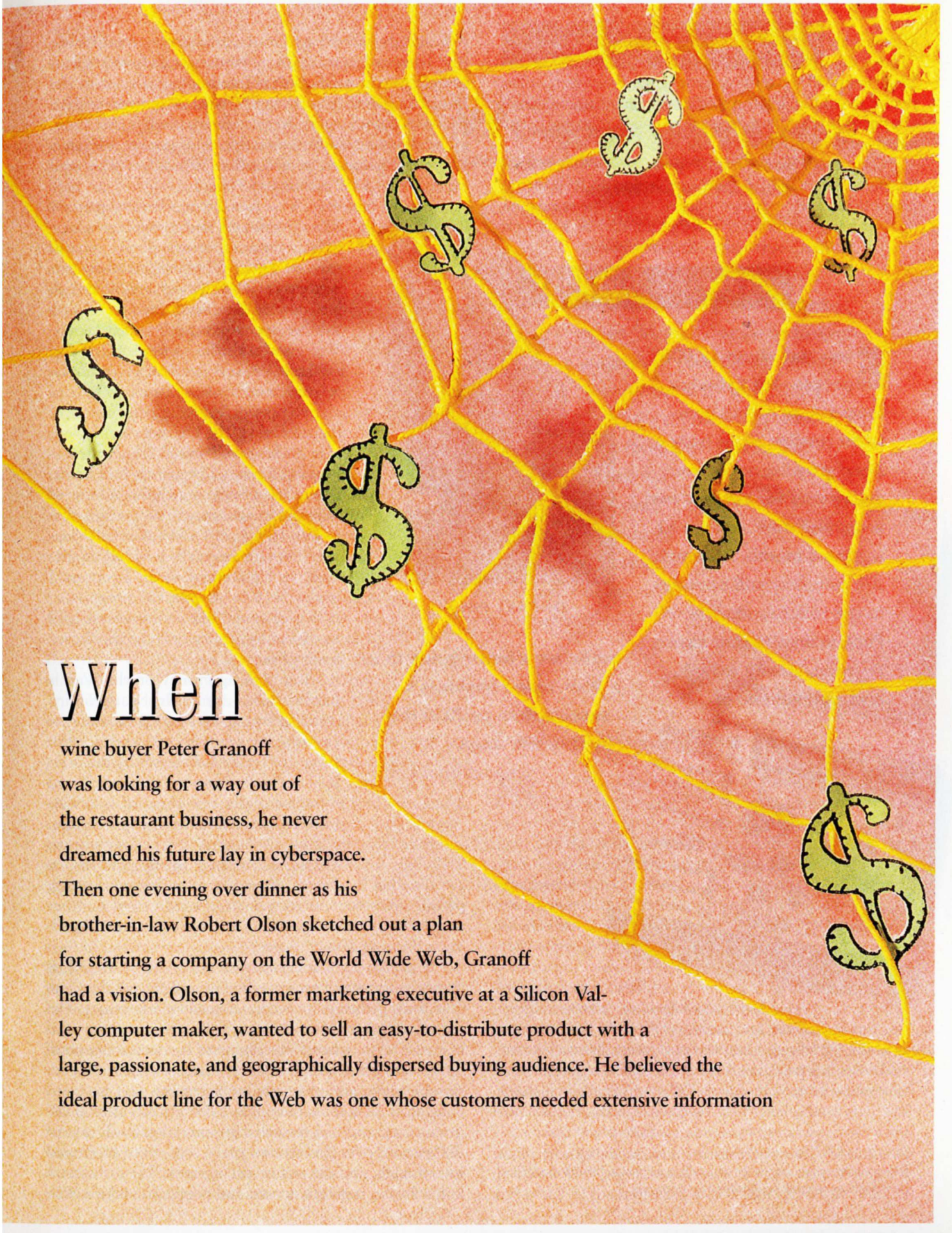
COMMERCE ON THE WEB

Is Web Business Good Business?

Although tangible returns are elusive, the first wave of Web-based companies have learned valuable lessons about how to make the most out of a presence on the Net.

BY MARK HODGES

ILLUSTRATION BY FRANKLIN HAMMOND



When

wine buyer Peter Granoff was looking for a way out of the restaurant business, he never dreamed his future lay in cyberspace. Then one evening over dinner as his brother-in-law Robert Olson sketched out a plan for starting a company on the World Wide Web, Granoff had a vision. Olson, a former marketing executive at a Silicon Valley computer maker, wanted to sell an easy-to-distribute product with a large, passionate, and geographically dispersed buying audience. He believed the ideal product line for the Web was one whose customers needed extensive information

to guide their purchasing decisions. An excited Granoff said, "You're talking about my business. Inspired, Granoff and Olson launched Virtual Vineyards, a rapidly growing online vendor of wine and one of the first of a growing number of companies that are illustrating the revenue-generating potential of putting a storefront on the World Wide Web.

Companies that continue to do most of their sales through conventional channels are setting up Web sites as promotional and corporate image tools. At the same time, the Net has given birth to a rising number of Web-only enterprises. It costs little to set up a rudimentary Web site that provides information on a company's products and services. And forecasts of the Web's business potential can be tantalizing. One often-cited source, Matrix Information Directory Services, predicts that the number of people online will expand from 57 million in 1997 to 377 million in 2000. According to a Nielson Media Research report, 2.5 million persons already have bought products or services on the Web. And Forrester Research, a market-research firm in Cambridge, Mass., predicts that Internet-based sales in the United States will jump from $518 million this year to $6.6 billion by decade's end. Over the same period, Jupiter Communications, a New York firm that studies online and interactive technologies, projects that Web advertising will expand from $312 million to $5 billion.

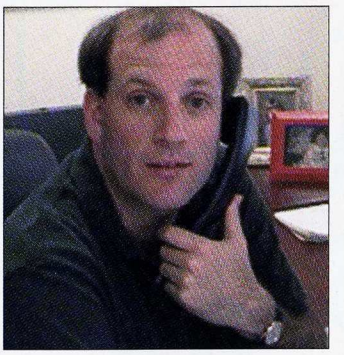
Internet businesses have found that cybershoppers are attracted by the ability to research and compare products before initiating transactions—in contrast to the world of brick-and-mortar commerce, where customers often rush into purchases or must travel from store to store to compare products effectively. Web sites can offer more detailed and extensive information than a typical customer-service representative is willing or able to provide, either in person or over the telephone. The Internet marketplace also may be well-suited for customers looking for rare or hard-to-find items. Mike Schachner, managing editor of *Wine Enthusiast* magazine, predicts that a Web-based outfit like Virtual Vineyards will do especially well selling specialty or high-priced wines, as opposed to the "$10 bottle of Cabernet to have with your steak" that consumers will still buy from local shops on the way home from work.

But making money on the Web is hardly a slam-dunk. Most early online retail ventures have failed to generate enough sales to survive, and a 1996 survey of online businesses by the market-research firm ActivMedia found that just under one-third of Internet-based firms claim to be profitable. Many consumers are unwilling to change established buying patterns, or are repelled by clumsy attempts at online marketing; people are reluctant to type their credit card number onto a Web site for fear that it will be stolen (*see "Building a Bond of Trust," page 26*).

Right now, most companies are trying to establish themselves as major presences online and playing the game of increasing their name recognition and market share. The payoff, these companies believe, will come down the road in a year or so, when Web commerce becomes more commonplace. For example, Darryl Peck, founder of Cyberian Outpost, an online computer retailer, says his company posts $2 million in monthly sales, attracts 12,000 visitors a day, and has recorded an annual growth rate of 600 percent over the last two years. Ask about profit and loss, though, and the picture isn't so rosy. The investment in hardware, network access, and people to make a Web

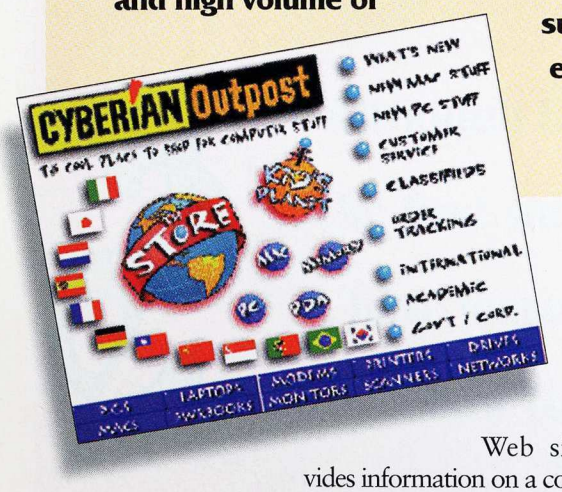
CYBERIAN OUTPOST

Every day about 12,000 people visit Cyberian Outpost, an online computer retailer. Sales have been growing at 600 percent a year for the past two years and now average $2 million a month. Although the company still operates in the red, founder Darryl Peck maintains that strong revenue, steady growth, and high volume of traffic are a better guide to a Web-based business's success than profit at this embryonic stage.



DARRYL PECK

www.cybout.com



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site efficient and attractive is substantial. Says Peck, "Our loss was under 9 percent of sales last year—that puts us a lot closer to profitability than most Web companies." At this embryonic stage of the Web marketplace, Peck maintains, strong revenue, steady growth, and high volume of traffic at the Web site—rather than net profit—are a better guide to a Web-based business's success.

Virtual Vineyards founder Granoff says that his company is growing at an average of 20 percent per month and that its "trend lines are all in the right direction." Preview Travel, which provides online travel and vacation planning information through America Online and its own Web site, claims to have 1.4 million subscribers, weekly bookings of between $1.2 million and $1.6 million, and a growth rate of about 20 percent per month. Hot & Spicy Foods of Morgan Hill, Calif., opened a Web site in November and saw an immediate spurt in business; sales during the first quarter of this year were double what they were during the same period of 1996, according to president Jeffrey Marcil. These and other successful sites emphasize transaction efficiency, rapid response, and tools for customizing the customer's visit. They frequently allow visitors to make contributions to the site or talk with each other in a way that makes them feel like members of a community.

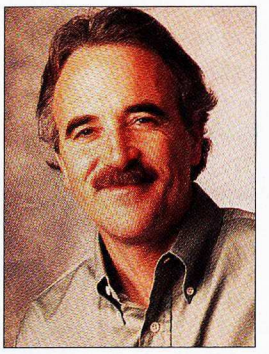
These cybermerchants are learning that even in a medium as exotic as the Web, all the rules of traditional business still apply. Companies need to get strong financial backing, find customers, offer high-quality products, process orders efficiently, and win repeat sales. But to survive the early shakeout period, Web-based enterprises must also do more than simply master these fundamentals of Marketing 101. Merchants need imagination to design shopping environments tailored to the Web's unique strengths and weaknesses.

Judging from the business climate on the Web, many companies have made rapid progress toward learning the craft of Internet marketing. Online retailers provide entertaining and informative sites that customize shopping for the individual consumer and even anticipate consumers' buying preferences. Despite such developments, the financial prospects of Internet commerce are hard to gauge. Information that has been released focuses on the cheeriest statistics the companies can muster, such as the number of visitors to their online stores and the rate of revenue growth. While this is an appropriate mentality for a start-up business, it can carry a company only so far. Eventually, costs must be covered. And as the novelty of the Web wears off, the challenge of offering a distinct and customer-friendly site becomes ever tougher—and more essential.

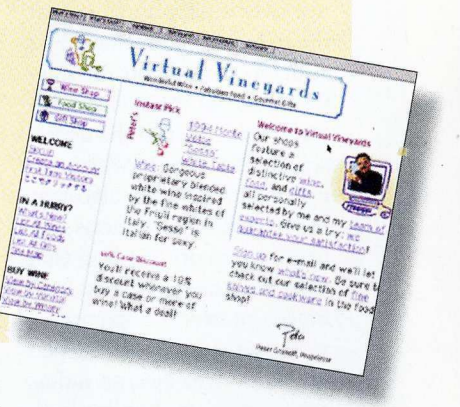
VIRTUAL VINEYARDS

Wine buyer Peter Granoff and his brother-in-law launched the idea of an online wine store over dinner as they brainstormed about marketing a product to a passionate but geographically dispersed clientele who needed extensive information to guide its decisions. Virtual Vineyards fosters a sense of community among its customers by publishing their tips on blending wine with food and offering an advice column called "Cork Dork." Granoff says the company is growing at an average of 20 percent per month.

www.virtualvin.com



PETER GRANOFF

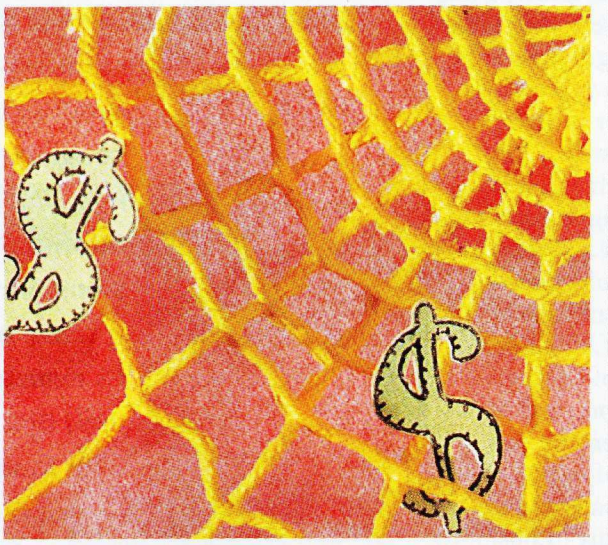


TAPPING THE WEB'S WONDERS

Many early-adapting businesses have struggled with how best to use the new medium. Commonly, companies fail to exploit the capacity for interactivity, offering static sites that serve as electronic versions of brochures. Successful companies, in contrast, have developed dynamic, information-rich sites that create an informal, often whimsical atmosphere that consumers enjoy searching whether they buy products or not, and that take advantage of the Internet's unique attributes. Good Web business sites offer visitors a wealth of useful, diverting information in addition to detailed product descriptions. Virtual Vineyards, for instance, publishes a "tasting chart" that helps shoppers learn how to judge wines by intensity, sweetness, body, acidity, tannin oak, and complexity. It also provides a glossary of frequently used terms and tips on how to mix wine and food and an archive of menus, including recipes and wine choices, for a variety of holidays and special occasions.

Online booksellers are also employing innovative ways to use free information to stimulate sales. Amazon.com devotes a Web page to each book that the cyberstore sells, and many of the more popular offerings feature links to

Building a Bond of Trust



NO MATTER how hospitable a Web site, consumers often remain reluctant to part with money through the Internet. Before the 1996 Olympics, for example, Nancy Davis of Atlanta dialed up an online sales site to purchase event tickets. But she almost gave up when a dialogue window asked for her Visa number and her mother's maiden name. Davis was hesitant about releasing such information casually—and certainly not over a telephone line, at the request of a machine. Her reluctance highlights the fragile bond of trust between buyer and seller in the depersonalized setting of Web commerce. Consumers also fear that online transactions will not remain private and that their purchasing habits will become a matter of record.

The situation is getting better. CommerceNet, an industry association of online businesses, is collaborating with the Electronic Frontier Foundation on a project called eTrust to address this concern. The eTrust system accredits Internet companies according to transaction security and their willingness to protect customers' personal information. Complying companies will be allowed to display "trustmarks" that indicate several levels of customer-friendliness. A pilot project involving as many as 100 companies and organizations is now under way, with global launch expected later this year.

Financial institutions, meanwhile, have established new types of payment schemes to enable the electronic equivalents of anonymous cash purchases on the Web. For example, a consortium of major communications and financial firms, including AT&T, Chase Manhattan, Dean Witter, and Wells Fargo, late last year created Mondex USA, a company that will offer a "smart card" for electronic-cash purchases on the Internet and in conventional stores. Consumers with the Mondex software first go to their regular bank's Web site to load their cards with cash value, which they can use to make anonymous online purchases. Merchants receive payment within seconds of the sale. Mondex USA has installed features that protect its "smart card" from theft, including encryption, digital signatures, and the option for password protection

Proponents of this virtual currency believe that the ability to make micropayments at prices as low as fractions of pennies will stimulate the Internet economy. For example, consumers who are unwilling to spend $50 a year to receive a periodical online might happily part with a few cents for a single article—or fractions of a cent to look at a small part of one article, or just to peruse the table of contents.

While advocates see micropayments making purchase of low-price items easier, skeptics contend that any scheme that rewards the vendor ade-

Many consumers still hesitate to buy through the Web out of fear that online transactions will not remain private.

author interviews and reviews by professional critics. Another Internet bookstore, PureFiction in England, not only reprints snippets of critical reactions to its featured offerings but also publishes sample chapters and offers five-minute audio excerpts of its books on tape.

Early-adapting companies have found that too much visual sophistication can be counterproductive. Frustrated shoppers bail out of business Web sites quickly when detailed renderings of products or other images take too long to load on their computer screens. ReadMe.Doc, a computer-book retailer in Chambersburg, Pa., recently scaled back on the number of graphic images on its site because "it was taking too long for someone with a 14.4-kilobit-per-second modem to get a page up," says president Christopher Kendall.

In a similar vein, Perry Lopez, creator of Hot Hot Hot, a hot-sauce retailer in Los Angeles, stresses the importance of easy navigation. He has tried to create a Web site where customers have to click only once from the home page to get to key information in any given category. But such an approach is a matter of personal taste; some Web users prefer pages with small amounts of information and frequent links.

Internet business experts caution would-be cybermar-

quately would require steeper prices, inhibiting the kind of frequent, casual use of Web sites that surfers now take for granted. They argue that most customers who buy information on the Web will probably still find subscription-based or advertising-supported products more economical than products priced à la carte. In all likelihood, the pay-per-view and subscription-based systems will coexist, offering consumers more choices and strengthening the versatility of the Internet as a marketplace.

Beyond the psychological barrier of uncertain privacy, Internet commerce may founder over a technical obstacle: the lack of compatibility between methods of processing Web transactions. Approximately 20 companies have developed software offering proprietary payment or security solutions, and these systems do not necessarily speak the same language. The inability of merchants and customers to readily authenticate one another's identity or agree on a type of payment threatens the free flow of Internet commerce, contends Jay M. Tenenbaum, chairman and chief executive officer of CommerceNet, an industry association of online business. "We're well down the path to digital anarchy," says Tenenbaum. What's needed, he maintains, is "a universal protocol between any wallet and any merchant."

Toward this end, CommerceNet collaborated with the World Wide Web Consortium (the group of organizations that sets standards) to create a common method for software to handle Internet payments. This effort has spurred development of eCo System—a translator that helps incompatible software used in Web business transactions to "talk" to each other. The eCo System framework provides a way for a variety of commercial processing software to communicate the basic information needed for a financial transaction. Tenenbaum believes eCo System will evolve into a common business language for automated transaction-processing on the Internet.

—*Mark Hodges*

keters that good Web site design takes time. It is deceptively easy to throw together a quick-and-dirty Web page in a few hours. But a high-quality site that customers will feel comfortable visiting and revisiting requires planning and maintenance. Successful electronic merchants make detailed studies of commercial Web sites before designing or opening an electronic business. For instance, Darryl Peck says he "spent 16 hours a day checking out Web sites" before formulating a business plan for Cyberian Outpost. Similarly, the founders of Amazon.com spent a year learning the business before going online, according to Scott Lipsky, vice-president of business expansion.

Web business veterans recommend bringing in outsiders or customers to evaluate a new site before launch. AMP, one of the world's leading manufacturers of electronic and electrical connectors, took a year to develop a Web site allowing online parts purchase. For almost six months before the site officially opened, major customers piloted the new system and offered comments on its usability, according to Robert Orendorf, project manager for AMP eMerce Internet Solutions. And Virtual Vineyards took nine months to develop a product inventory system to support the company's Web site, accommodating more than 75 wineries and 45 specialty-food companies.

Attracting and Keeping Customers

There's nothing so forlorn as an unvisited Web site. Companies that want to attract people to their online storefront use a variety of channels, both on and off the Internet, to attract potential customers. One approach is to send marketing offers to customers through electronic mail. Such efforts need not be the kind of unsolicited junk mail, or "spam," that so enrages many recipients. Many Web sites ask visitors to register, a process that offers the option of signing up for e-mail from the company announcing product news.

One technique that universally attracts customers to a Web site is visualizations of products. When engineers search the AMP Connect Web catalog, for example, they can navigate among 70,000 choices by part name or number, or by using a menu of product pictures. Once customers have found products meeting their specifications, they can view detailed line drawings, and in some cases, download three-dimensional renderings. At Toyota's Web site, customers can not only read text screens with detailed product specifications and dealer locations but can see what a variety of colors look like on a car model, view new automobiles from different vantage points through photographic "walkarounds," and look at interiors through a special "photobubble" view like that provided by a fisheye lens.

Granted, such attempts to visualize cars are primitive compared with what consumers see when visiting an automobile dealership. And shoppers often have to go through an involved process of downloading free software to use such effects. But car buying on the Web has proven surprisingly popular, especially in the form of online brokering services that gather product information and handle transactions. The Auto-By-Tel site, for example provides access to financing and insurance information as well as an electronic form for requesting no-haggle, no-obligation price quotes on specific car models. Since starting up in 1995, the company has processed 325,000 requests for quotes from a network of 1,500 accredited dealerships. One participating dealer—Atamian Honda–Volkswagen of Tewksbury, Mass.— credits Auto-By-Tel for initiating as many as 25 percent of its sales.

In the San Francisco Bay area, the 12-dealership Tasha Automotive Group has sold several hundred cars through another Web-based buying service, Autoreach, according to

Jon Fisher, director of operations. Although those represent less than 5 percent of total sales, Fisher expects more than 20 percent of his company's sales to come from the Internet within five years, based on recent growth trends. Fisher is particularly excited about the potential of Web sites to alleviate consumer disgust with the high-pressure sales and marketing tactics common in the automotive business.

Building Electronic Communities

Surfing the World Wide Web can be an adventure, but online users are often eager to relieve the loneliness of the ride. Many Internet businesses are trying to tap into the desire for interpersonal connection by establishing hospitable sites. People need to feel that someone is listening and responding on the other end of the modem.

While fast and consistent response is a basic of good business in any case, entrepreneurs have found its importance magnified on the Web. Shoppers want some confirmation other than a message box on a Web site that their orders have been processed. The rapidity of e-mail transmission has accustomed Internet users to expect responses to their questions and concerns within hours instead of days. Scott Lipsky of Amazon.com says that the company strives to answer every e-mail note—usually within hours. With the site's business growing by 30 percent each month, this task has become more daunting with each passing week, and the bookseller has continually beefed up its staff to meet this demand.

Business Web sites also gain by fostering a sense of community among their visitors. The first prerequisite of community-building is to offer a place "where people want to hang out," says Lee McKnight, a specialist in Internet economics and a lecturer in MIT's Technology, Management, and Policy Program. One way to do so is to address visitors in an informal, often humorous tone that encourages customers to have fun while making purchases or gathering product information. Visitors to Van den Bergh Foods' Ragú sauce site, for example, enter a cozy dining room dubbed "Mama's Cucina" where a grandmotherly woman waits at a table set for two. A dialogue bubble over her head says: "You're buying a new computer? What's this new new all the time now? I've got pots and pans older than you." In similarly colloquial language, Mama offers visitors recipes, Italian lessons, a free vacation contest, and advice on one's love life, along with information about Ragú products.

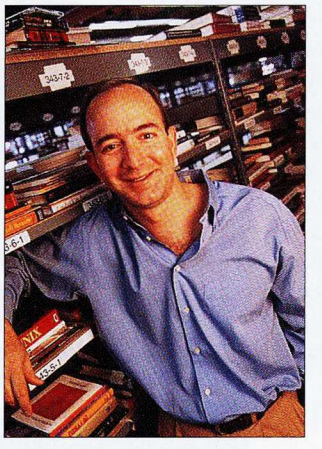
Some online businesses encourage a sense of community by allowing customers to contribute information to their sites. Virtual Vineyards publishes consumers' favorite ways to marry wine and food while offering the "Cork Dork"—a column that answers customer questions about wine. Amazon.com invites readers to post their comments about books it sells alongside those of professional critics.

Another tactic for building community is to emphasize interaction among customers. An excellent illustration of this approach is Onsale Inc., which conducts several virtual auctions a week of refurbished computers and home-electronics products. Shoppers can not only follow the progress of the auction and enjoy the pleasure of the hunt but can also include personal comments with their bids—and read those of other buyers. "They often get into competitive interactions, making comments like 'No way, MP of Mountain View, it's mine!!'" says marketing director Michelle Pettigrew. Onsale also stirs the pot by soliciting comments from bidders on topics not directly related to the purchase, posing questions such as "What's your favorite personal-computer game?" These interactions, says Pettigrew, help ensure that the auction is "not just a static

AMAZON.COM

Amazon.com, the Internet's leading bookseller, devotes a Web page to each book it offers. Many of the more popular offerings also include links to author interviews and reviews by professional critics; visitors to the site can post their comments alongside. Before starting the company, president Jeffrey Bezos learned the complexities of online transactions while working on Wall Street, where he helped design computer models to manage investment funds. He says sales are growing 30 percent each month.

www.amazon.com



JEFFREY BEZOS

A Privacy Safety Net

Why Web commerce needs a new law.

BY REP. EDWARD J. MARKEY

THE wondrous network that is bringing new services to homes, businesses, and schools has a certain Dickensian quality to it: it will be the best of wires and the worst of wires. It can uplift society and it can debase it.

The World Wide Web can promote electronic commerce, democratize mass media, and allow people to telecommute to work and educate themselves. But this same technology makes it possible to track where people are going on the Net and what they're doing there—to sneak corporate hands into a "cookie jar" of personal information to compile profiles of hobbies, buying habits, financial status, health, and who they associate with online. In short, that wondrous wire may allow digital desperadoes to roam the electronic frontier unchecked by any high-tech sheriff or adherence to any code of electronic ethics.

Some sites on the Web, for example, transfer a small file—called a "cookie"—to the hard drive of a visitor's computer. If a person returns to that site, the cookie file will identify the user as a repeat visitor. Many companies' Web sites use these cookies—unbeknownst to the user—to keep track of what other sites a person visits and thus learn more about his or her interests and online habits. Marketing companies are also selling electronically maintained driving records, land titles, property-tax records, court records (bankruptcy, divorces, civil and criminal actions), occupational licenses, Securities and Exchange Commission filings, and political contributions.

These records help reveal information about an individual such as marital status, age, social security number, height and weight, date of birth, medical condition, political party, and assessed home value. Recently one such firm advertised online that its service allowed Web businesses and advertisers "to target content to demographic audiences so precise they can reach markets as narrowly defined as a single customer."

With so much personal information circulating, the question arises as to how we ensure a common trust that will enable the early communities on the electronic frontier to take root and grow. Online commerce will succeed only if it can foster trust by ensuring security and privacy through an enforceable code of electronic ethics. Without such a code, the Net could degenerate into a Wild West-like environment. We can't expect everyone to be cyberspace versions of John Wayne or Annie Oakley fighting the bad guys. It won't work.

I have therefore proposed legislation that would establish a Privacy Bill of Rights for the information age. Consumers, I believe, should have a right to privacy regardless of whether they are conducting business using a telephone, a TV remote-control clicker, a satellite dish, or a modem.

Boiled down, the right of privacy encompasses three core concepts, which I abbreviate as "Knowledge, Notice, and No."

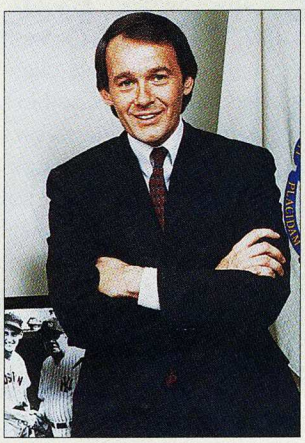
•KNOWLEDGE: Companies should inform consumers when they are collecting personal information. Web sites that use cookies to surreptitiously glean personal information violate this principle.

•NOTICE: Companies should conspicuously notify consumers of any intent to reuse or sell personal information they collect.

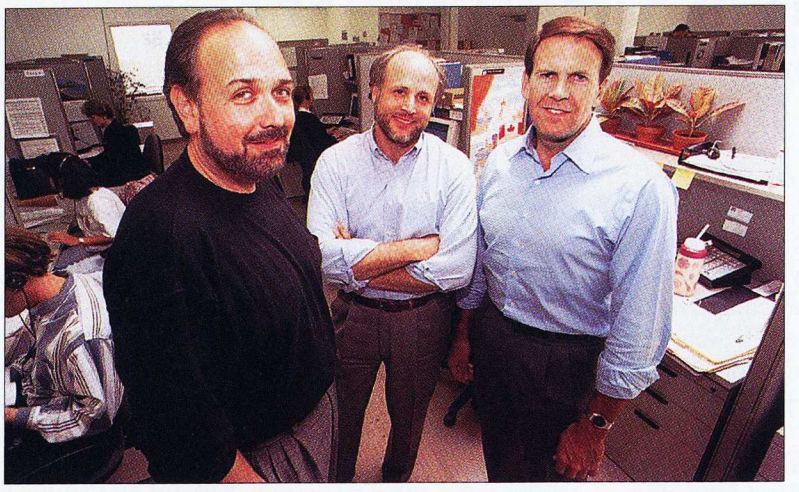
•NO: Consumers have the right to curtail or prohibit reuse or sale of their personal information.

My legislation—the Communications Privacy and Consumer Empowerment Act—gives the Federal Communications Commission and the Federal Trade Commission one year to analyze how to put these three privacy rights into practice. Some of the answer will lie in industry-set standards and self-regulation. Another part of the solution lies in technologies that consumers can use to protect their privacy, such as software that blocks Web sites from reading cookies off the user's hard drive.

But with or without industry cooperation or software aids, consumers need legally enforceable privacy rights—period. Some of the practices of companies operating in cyberspace simply ought to be against the law. Thus, my legislation will require the FCC and FTC to safeguard those rights. Those agencies would serve as legally binding regulatory backstops—a safety net—guaranteeing a minimum level of privacy protection where the marketplace and technology fail to protect the public interest. It is our responsibility to improve consumer privacy while the Net is in its commercial infancy. ■



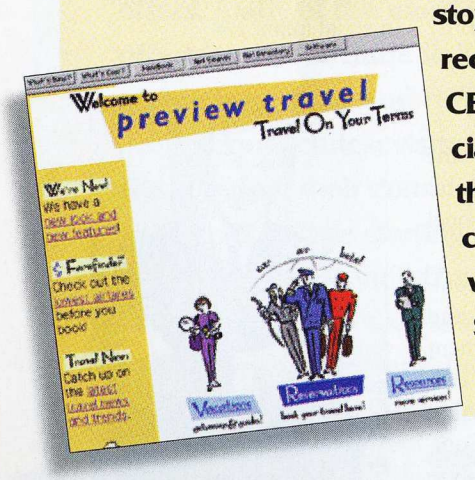
EDWARD J. MARKEY (D-Mass.) is the ranking Democrat on the House Commerce Committee's Subcommittee on Telecommunications, Trade, and Consumer Protection.



KEN ORTON, JIM HORNTHAL, DAVID LAMBERT

Preview Travel's site allows fliers to compare air fares and book flights by entering their destination and preferred dates, times, and airline. The screen then returns a selection of matching flights, along with the fare, seat availability, type of airplane, meals, number of stops, and the flights' on-time records. Chairman Jim Hornthal, CEO Ken Orton, and chief financial officer David Lambert initiated the online service in 1996; the company now claims to have weekly bookings of between $1.2 million and $1.6 million.

www.previewtravel.com



online catalog or order-taking mechanism."

Onsale's strategy of combining entertainment with retailing appears to be paying off. The company says it has attained profitability with monthly sales exceeding $4 million. And according to PC Meter's recent audience rating reports for the World Wide Web, the online auction house often attracts visitors for more time each month than any other Internet shopping location. Between August 1996 and January 1997, Onsale shoppers spent an average of 30 to 48 minutes on the site each month.

Businesses gain further important advantages by maintaining strong electronic-mail contacts with customers. "A lot of times all you have to do is ask your customers for their opinions and feedback and you get a statistically reliable sample in a matter of hours," says Onsale's Pettigrew. "We use our customers as a sounding board whenever possible." Rosalind Resnick, president of a Web-site design company called NetCreations, considers the three hours a day she spends answering mail from customers as time well spent. "Customers are thrilled to get a response from the president of the company," she says. "The more interaction the better."

Indeed, Hot & Spicy Foods president Marcil says that what he likes best about adding an Internet component to his business is the rapid access it gives him to customers. He can make a change in product offerings and get the word out immediately to customers—both on his Web site and through targeted electronic mailings to regular cybershoppers at his store. The response rate to e-mail specials is around 5 to 7 percent, he says, in contrast to the 3 to 4 percent response elicited by traditional targeted mailings.

Customized Shopping

Successful online businesses have even found ways to tailor the shopping experience to individual buyers. These innovators give consumers tools that ease product searches or profile individuals' buying preferences and offer information tailored to their needs.

A good example is Preview Travel, where consumers have access to a powerful engine for customizing their trip plans. A would-be shopper enters a destination and preferred dates, times, and airline. An automated flight-planning system then displays a selection of flights that match the desired itinerary—including fare, seat availability, type of airplane, meals, number of stops, and the flight's on-time record.

Preview also offers best-fare options, reflecting the fact that the difference in cost for relatively small changes in plans can be significant. For instance, a recent request for a round-trip quote from Atlanta to Sydney, Australia, came in at slightly over $3,000 for the preferred times. The best-fare quote reduced that price nearly 50 percent by shifting the departure time for the Los Angeles-to-Sydney leg of the

The Neverhood of Internet Commerce

TR's Culture of Technology columnist wonders whether the convenience of online shopping is worth the ensuing social and economic chaos.

BY LANGDON WINNER

NEW technologies sometimes offer an illusion of benefit that holds true only within a narrow economic frame. While we eagerly chase the savings in money and effort that a new tool seems to offer, we may disregard the wider, social costs that may eventually mock our sense of prosperity.

This bane of false economy haunts today's push for Internet shopping. A vast cybermall has recently moved into every village, town, and city, selling clothing, CDs, computers, automobiles, and other products to millions of potential customers. Digital entrepreneurs predict that people will relish the convenience of buying things on the Net, flocking to stores whose electronic doors are always open and where parking is never a problem.

The hoped-for bonanza of Internet commerce has not yet materialized; most online establishments are still in the red. But a few retailers have begun making strong inroads into traditional business domains, especially in the realm of book selling.

At first glance electronic book vendors such as Amazon.com, Book Stacks Unlimited, and others have much to recommend them: enormous catalogs searchable by home computer, 24-hour-a-day service, literary reviews on the Web, and other nifty services. Amazon.com, for example, carries 1.5 million English-language books, roughly 10 times the number available in the largest conventional stores. Adding to their appeal, Internet sellers typically offer impressive discounts of 10 to 40 percent.

But before we shift our purchases to Internet vendors, we need to recognize a hidden price we may end up paying: the demise of traditional shops. A bookstore is first and foremost a gathering spot for those who care about books and reading. In these places the purchase of a product is only part of the experience. As we enter the stacks, we often expect to talk with store clerks or other patrons about what's new or interesting in a particular genre.

This aspect of browsing is especially important for children as they approach a life with books. "I'm finished with all the Brian Jacques stories," my son recently announced to Muriel, proprietor of a bookshop in our town. "Are there any more of that kind?" The kindly white-haired woman raised her eyebrows, smiled, and led him up the stairs to a shelf of children's novels, enthusiastically describing each volume. The $9 we paid for the book cannot approach the real value of Muriel's gift—a child's heightened sense of the horizons between two covers.

Some will argue that fast search engines supplemented by online help desks can replace the human touch that traditional stores have to offer. But this reflects an impoverished understanding of what the social life of books involves. Even if a Web site learns our names and buying habits, even if it automatically notifies us when "books you want to know about are published," can it connect us to the world of living readers, the place where the pages come alive? I don't think so.

The personal benefit that bookstores and other local shops provide is magnified by the way they buttress the civic culture of our towns and cities. One sign that a community is flourishing is the presence of well-maintained, well-stocked shops in downtown and neighborhood centers. There is now widespread awareness that the arrival of huge, corporate superstores tends to kill small businesses, leaving main street with boarded-up buildings, prey to the social ills that spread when the economic core of a community expires. It is this realization that has spurred citizens in many towns to band together to resist the coming of Wal-Mart and its ilk.

But I wonder if those residents newly vigilant about megastore sprawl are aware that potentially greater destruction will occur as people abandon local concerns to start buying online. The threat to those concerns from Net vendors is far more insidious than that posed by the large national chains. Communities may summon their powers to unite against a Borders or Wal-Mart. But QuickBucks.com will creep in under their radar screens. Many shops survive on a precarious margin and are not robust enough to withstand the onslaught of electronic commerce. If 10 to 15 percent of the sales of your local bookstore quietly migrates to the Internet, it's likely that the shop will eventually fold.

This suggests that we will have to become more judicious about where and how we make purchases. In my view that means avoiding Internet commerce when there are reasonable, local sources of supply. It is not a question of altruism, but of self-interest broadly conceived. The short-term advantage of sending money to a data-processing organization in Seattle for a bargain-priced book makes no sense if the action depletes the economy down the street and undermines the integrity of community life.

Yes, we should use every Internet resource to explore the market and make intelligent comparisons. But when it comes to casting "dollar votes," we can better spend the money closer to home, in a neighborhood where people actually live rather than the neverhood of digital bits. ■

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flight from late afternoon to early evening, and by changing the trip home from Sydney from around noon to mid-afternoon. While the same services are available from traditional travel agents, booking air tickets over the Web lets the consumer transact business at any hour of the day or night, and do comparative shopping.

Other Internet-based businesses are taking customization into a new dimension with software that digests information from consumers and then responds to their buying preferences. The Vertigo Group, for example, recently introduced One-on-One Banking Center software, which banks can make available for their customers to download from Web sites. The software leads consumers through an "interview," eliciting basic personal information as well as details about their assets, debts, and investments. One-on-One then generates an "action plan" with recommendations for investing a specific amount of money in an equity mutual fund, opening a tax-deferred annuity at a given dollar level, or purchasing an individual retirement account.

One-on-One then identifies products offered by the sponsor bank and provides screens on which customers can get more specific information—for instance, they might ask to see certificates of deposit that earned given rates of return over the past 10 years. If consumers cannot get all of their questions answered through the One-on-One interface, they can send an e-mail message to the bank. When they are ready to make purchases, the software provides a means of doing so online.

Intelligent-agent technology promises to offer an even more ambitious means of customizing online shopping. Now in its infancy, agent software allows business Web sites to ask participating customers questions or track their buying preferences and use this information to anticipate future needs. The agent for an online company can then send product announcements or news that consumers might find interesting. Eventually, individual shoppers may maintain their own intelligent agents that would continually scan the Web for information or carry out specific shopping assignments.

One early example of intelligent-agent technology at work can be found on The Firefly Network. New members fill in forms on the screen, rating their preferences for musical groups and movies. Armed with this data, Firefly—a free service—will give them information about music and videos that matches their expressed preferences, and inform them when members with similar interests are available for conversation in the Web site's chat rooms.

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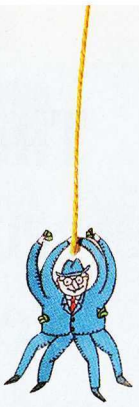


When Pull Comes to Push

In the first heated year or so of Web business, most of the action has revolved around efforts to tap the consumer market. More recently, as the Web proved to be more than a fad, companies have started to buy and sell products and services with one another. Such business-to-business sales make sense because businesspeople typically know what product they're looking for, according to Joseph Bailey, an MIT doctoral student who has written extensively about Internet economics.

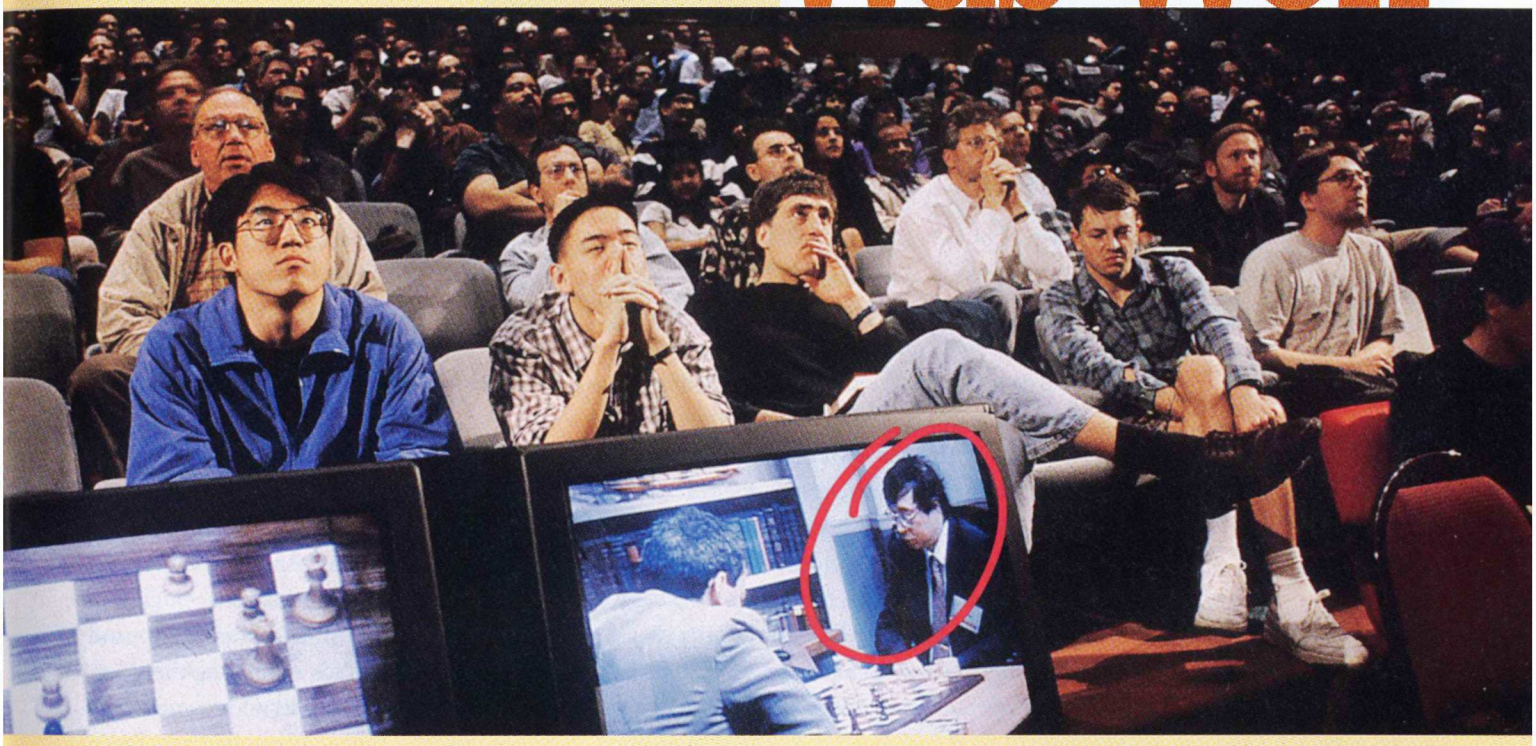
Nonetheless, many companies still hesitate to use the Web because of doubts about its reliability. "Businesses need to feel they can trust the pathway between them and the supplier," says senior analyst Blane Erwin of Forrester Research. Some companies are limiting the risk by conducting online transactions only with established business partners who are given access to the company's private intranet.

Another major shift in the model for Internet commerce concerns the technology available for marketing. Until recently, Internet marketing activities have focused on strategies to "pull" customers into sites. In the past year, however, software companies have developed tools that allow companies to "push" information directly out to consumers, transmitting marketing messages directly to targeted customers. Most notably, the Pointcast Network uses a screen saver to deliver a continually updated stream of news and advertisements to subscribers' computer monitors. Subscribers can customize the information they want to receive. By clicking on intriguing advertisements, they proceed directly to a company's Web site. Companies such as Virtual Vineyards are already starting to use similar technologies to push messages to customers about special sales, product offerings, or other events. But push technology has earned the disdain of many Web users. Online culture exalts the notion that the information flowing onto the screen comes there by specific request. Once commercial promotion begins to fill the screen unbidden, the distinction between the Web and television fades. That's a prospect that horrifies Net purists.

But it is hardly inevitable that companies on the Web will need to resort to push strategies to make money. The examples of Virtual Vineyards, Amazon.com, and other pioneers show that a Web site selling the right kind of products with the right mix of interactivity, hospitality, and security will attract online customers. And the cost of computing power continues to free fall, which bodes well for any enterprise setting up shop in silicon. People looking back 5 or 10 years from now may well wonder why so few companies took the online plunge.■

An Interview with Deep Blue's Brains

How the Chess Was Won



Feng-Hsiung Hsu, the principal designer of the IBM supercomputer that beat Grand Master Garry Kasparov, asserts that the win means we can chalk one up for humanity.

When world chess champion Garry Kasparov abruptly resigned the sixth and final game of his match in May against Deep Blue—a.k.a. the IBM RS/6000 SP supercomputer—a machine finally fulfilled one of the oldest challenges in artificial intelligence. Chess has tantalized computer researchers since the 1830s, when the eccentric English inventor Charles Babbage thought of luring investors to his idea of a programmable "analytical engine" by holding out the possibility of a chess-playing machine. After all, the rules of chess are precisely defined and easy to program, yet they give rise to strategic complexities that challenge the finest human minds. But despite researchers' best efforts, no machine proved able to beat the finest human players. **Until Deep Blue.**

PHOTOS: IBM

It takes a village: Feng-Hsiung Hsu (front), Joe Hoane (left), and Murray Campbell were among the Deep Blue team members who sharpened the computer's skills after it lost to Garry Kasparov last year.

Ironically, the victory comes when the computer-chess community has long abandoned any pretense of mimicking human thought. Chess masters, like the rest of us, are now known to reason by recognizing patterns, forming concepts, and creating plans—processes that computers do poorly, if at all. Deep Blue, like all the top chess-playing machines since the 1960s, relies instead on brute force—it looks as far ahead as it can at all possible moves and evaluates the strength of each position according to preprogrammed rules. Because of the rule that the faster the computer, the more positions it can search and the better it can play, Deep Blue relies on 32 high-speed processors operating simultaneously, each coordinating the work of 16 special-purpose "chess chips" that run in parallel. This computing firepower enables Deep Blue to evaluate a total of 200 million positions each second.

M. Mitchell Waldrop, author of the best-seller *Complexity* and of a forthcoming book on the history of computing, recently spoke with Deep Blue's principal designer at IBM, Feng-Hsiung Hsu, about the implications of the machine's victory and its value for other uses.

TR: In February 1996, when Deep Blue was brand new, it went up against Garry Kasparov and lost. Many people felt vindicated—as if that proved the human mind's innate superiority over a mere machine. But now that Deep Blue has won, many feel as if the computer has humbled humanity. Should they feel threatened?

HSU: No. Remember, Deep Blue didn't play chess by itself. Before the match even started, humans programmed the machine to rise to Garry's level. And then during the match we actually went in between games, looked at Deep Blue's mistakes, and adjusted its criteria for evaluating the situation accordingly, so it wouldn't make the same mistake twice. Without that, Deep Blue could not have competed with Garry. So you could say that last year, Garry won one for humanity's past. This year, Deep Blue won one for humanity's future.

TR: How so?

HSU: When Garry plays chess, he is relying on the intellect he is born with, his knowledge of the game, and the experience he has gained from playing both people and computers. This is the old-fashioned way of playing chess; Garry, despite his brilliance, is limited by what is biologically possible. Deep Blue represents any technology that allows us to exceed the limits nature normally imposes on us. Right now we're talking over the telephone: just by shouting I

Between moves for Deep Blue this past May, IBM's Hsu sat back calmly while Kasparov ruminated.

cannot reach you. The principle is the same with chess. Garry may be the top player ever in chess, but while the chess players on Deep Blue's team can't claim to reach anywhere near Garry's ability, with Deep Blue we exceeded our limits and won.

TR: When you put it that way, the match sounds a little unfair. Garry wasn't playing against one machine or even one person but a whole team.

HSU: But Garry was also part of a team. Between games he would consult with his coach, and even his own chess computer, to find out more about what Deep Blue would do. That is actually a normal part of any master's-level chess match. So you could say that Garry was playing against a computer relying on human power—but Deep Blue was playing against a human relying partly on computer power.

TR: Fair enough. But you could have said that last year when Garry won. Yet this year he lost. What made the difference?

HSU: The most obvious differences are that Deep Blue was twice as fast this year because it had new central-processing-unit chips, as well as twice as many chips designed only for the purpose of playing chess.

But for the match those hardware advances weren't as critical as two other considerations. First, we addressed the knowledge gap. Garry is a remarkable human being, with vast stores of knowledge and intuition about chess gained over 30 years of playing. Last year Deep Blue went into the match as a newborn baby: it had just been built and didn't know much about chess. So afterward we asked International Grand Master Joel Benjamin to come in with us and essentially take the machine to chess school. Actually, we went to chess school and used what we learned to completely reprogram the machine's basic software code and redesign the chess chips to incorporate much more chess knowledge. By this year's match, in Joel's words, Deep Blue had started to play human-level chess.

Second, we addressed the question of continued learning on Garry's part. For a computer scientist, the idea of building a machine to compete with the world chess champion is like climbing Mt. Everest. Unfortunately for us last year, the human Mt. Everest grew 100 feet a day while the match was proceeding: Garry has a human being's ability to adapt to what Deep Blue is doing. We knew that Deep Blue would never be as adaptive as a human, since that's not the way a computer is constructed. But we built software tools that allowed us to go in between the games and adjust Deep Blue's programming much faster than we could before. That turned out to be critical. The situation was like competing in the Indy 500, where you go to the pit stop and use your own high-speed tool to change the wheel.

What Deep Blue lacks in looks it makes up for in skills useful in sifting through vast amounts of information.

TR: As you note, Deep Blue isn't as adaptive as a person. You and your colleagues have emphasized again and again that the com-

The Kasparov–Deep Blue rematch exuded celebrity glamour, complete with commentators.

puter operates by numerical brute force. Why not try to simulate human cognition and adaptability?

HSU: While people are very good at pattern recognition, concept formation, and so on, those tasks are very difficult for computers. Computers can complement humans, however, because they're good at calculations. So from an engineering point of view, if you want to attack chess problems by computer, you figure out how to use the ability of the machine to calculate fast.

The ability to compute quickly is quite useful in many other fields. One application is called data mining. Big organizations use this technique to extract select information from a vast number of details—for instance, businesses employ it to analyze financial markets. Data mining could also help solve a myriad of problems for individuals, such as the information overload people are now experiencing in the wake of increased access to, among other entities, the Internet. Just as we used our special-purpose chess chips to speed up Deep Blue—employing many of them in parallel—we can create computer systems good for data mining the World Wide Web. Such technology could find and present you with information in a nutshell so that you don't have to spend your whole life surfing the Web.

TR: Wouldn't such a tool reinforce what one might call the "quantification fallacy"—the notion that all judgments and decisions can be reduced to calculations?

HSU: That danger exists. But data mining eventually leads to the discovery of empirical findings and rules, after which people stop to figure out why those exist. In other words, we can use computers to extract knowledge from data, but human beings still have to turn that knowledge into wisdom. That's how humanity progresses.

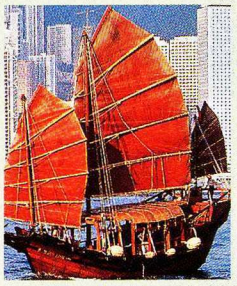
TR: What's next, now that Deep Blue has beaten the foremost human chess master?

HSU: Deep Blue's basic search blueprint is actually not specific to chess. So we've started looking at other areas such as pharmaceutical research, where Deep Blue could help design new drugs faster. That's important, since if a disease is very deadly and also very contagious, we need to be able to fight it with the best tools we have. Toward that end we are designing a molecular-modeling chip—one that can help predict how a candidate drug molecule would interact with, say, the protein envelope of a virus. We plan to install a number of such chips in a computer next year.

TR: Having come this far with Deep Blue, what would you say would actually constitute artificial intelligence?

HSU: Deep Blue would exhibit real AI if it would not allow me to unplug it. ■

Cruise...



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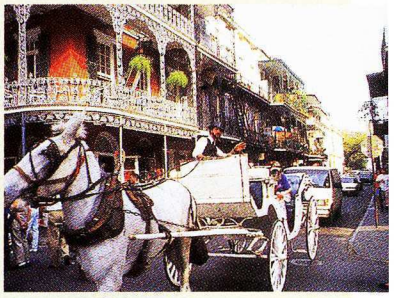

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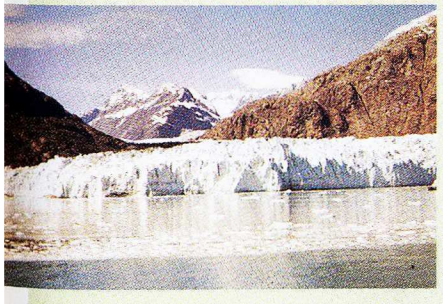

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PENETRATING THE RIDDLE OF HEART ATTACK

Many people who are vulnerable to a sudden attack don't know it because researchers have yet to pin down all the risk factors. But clues are accumulating—and many of them suggest new preventive measures.

THE DEATH TOLL from heart ailments remains the nation's largest disease problem. The human suffering has been compared in scope to several fully loaded jumbo jets crashing each day. And the economic cost for medical care and lost productivity will total about $167 billion this year, according to the American Heart Association. Moreover, contrary to popular opinion, heart disease is not an easy way to go. Just ask

BY HOWARD L. LEWIS

anyone who has suffered the searing pain of angina, survived a heart attack, or undergone heart surgery. Nor is heart disease the exclusive province of older people. Children have never been exempt. An estimated 32,000 babies are born each year with congenital heart defects, and early signs of heart disease can be found in teenagers and young adults who consume high-fat, high-cholesterol diets. People in these age groups are putting themselves at risk by gaining more weight, exercising less, and smoking more, too. And heart disease among people in their forties and fifties may soon become a great deal more common. Indeed, as baby boomers enter middle age after living a life of affluence, we may face a twenty-first century epidemic.

Heart pain and suspected heart attack lead Americans to call the 911 emergency system or visit a doctor or a hospital about 6 million times a year. About 10 percent of the time the problem is a bonafide heart attack; the other 90 percent of the time it's gallbladder pain, indigestion, a panic attack, or something else entirely. But about 2 to 3 percent of those sent home with a diagnosis of no heart attack incur an attack in the next day or so, according to Thomas J. Ryan, chief cardiologist at Boston University. "Patients don't appear at the ER with acute myocardial infarction [heart attack] tattooed on their foreheads," he notes. "Sometimes you just can't diagnose this disease."

An even bigger mystery is exactly who is at risk. The truth is that the medical profession often does not know. In fact, of the 50 percent or so of heart-attack deaths classified as "sudden," meaning that death comes within an hour, about one-fifth to one-third occur in people with no previously identified risk factors. Yet we are learning more and more about heart disease. Researchers are closing in on a range of suspect risk factors. And the answers they find could suggest innovative prevention strategies as well.

Cardiologists are intrigued by the possibility of a family of heart-attack genes.

MICROBES AND GENES

One somewhat surprising potential risk factor is the presence of bacteria and viruses in the blood. While these microbes may not directly cause heart disease, the infection they do cause appears to affect the endothelium, a thin, protective layer of cells that lines blood vessels. The result may be atherosclerosis, in which deposits of smooth muscle cells, calcium, and cholesterol build up, reducing blood flow through the coronary arteries that provide blood to the heart. Such deposits, called plaques, also provide sites where clots may form, further blocking blood flow and setting the stage for heart attack.

Researchers at Cornell University have done pioneering work implicating an avian herpesvirus as the cause of an atherosclerosis-like disease in chickens. Biochemist David P. Hajjar of Cornell Medical School has expanded that work to humans. He has demonstrated that the common herpes simplex virus can stimulate the production of "blood factor X," a binding protein that helps anchor other proteins to the blood vessel wall, where they form atherosclerotic plaques. The lab team has also shown that herpesvirus prompts the production of thrombin, a blood-clotting enzyme, which makes impaired blood flow even more likely.

The U.S.-based study Atherosclerosis Risk in Communities, begun in 1987 and conducted on 16,000 men and women ranging in age from 45 to 64, is providing still more evidence that viruses may help bring on atherosclerosis in people. The project manager, epidemiologist A. Richey Sharrett of the National Heart, Lung, and Blood Institute in Bethesda, Md., says the subjects' blood samples, which have been checked for antibodies that the body manufactures in response to specific viruses, have also been tested for clot-promoting factors, as well as for lipoproteins, the fatty proteins that envelop cholesterol and carry it through the bloodstream. One type is high-density lipoproteins (HDLs), which appear to protect against atherosclerosis; another major kind, low-density lipoproteins (LDLs), tend to promote the development of cholesterol-laden plaques within arteries.

Interestingly, blood samples with antibodies for type one and type two herpesviruses have turned up the kinds of clot-promoting factors and lipoproteins suggestive of heart-attack risk. And researchers have found that the same is true of blood samples with antibodies to cytomegalovirus, another virus of the herpes family. They have also noted a strain of bacteria called *chlamydia pneumoniae* in people with atherosclerotic plaques. University of Utah scientists reported in June 1996 that they had discovered this strain of bacteria in diseased tissue taken from 66 of 90 patients who underwent surgery to clear a blocked coronary artery. Evidence of the bacteria appeared in only 1 of 24 patients who did not have coronary disease.

Another promising area of study is genetics: researchers, including many cardiologists, are intrigued by the possibility of a family of heart-attack genes. Some especially troublesome members of this family are the recently discovered genes for "long QT syndrome," a disease affecting children and young adults. It strikes insidiously, much like crib death. The warning signs are spells of fainting during exercise, unconsciousness during sleep, or episodes of sudden fright or other unexplained emotional distress. The peculiar name of the syndrome derives from the way electrocardiograms, which track electrical activity in the heart, are recorded: readings for each heartbeat are divided into a waveform

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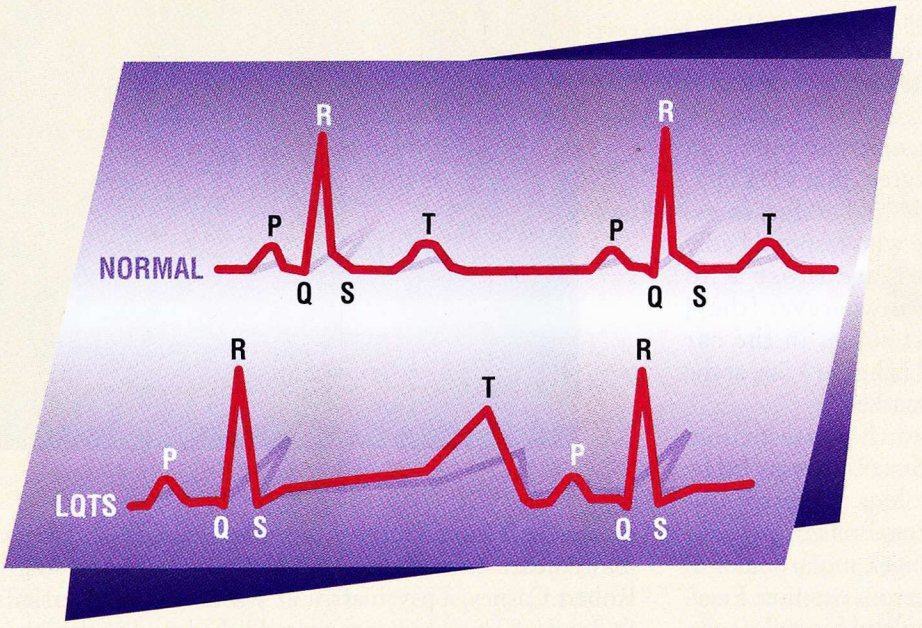
with key reference points called P-Q-R-S-T. With long QT, the interval between Q and T is 500 to 600 milliseconds at a heart rate of 60 beats per minute, in contrast to the normal interval of 400 to 440 milliseconds. Long QT engenders irregular heartbeat and an insufficient supply of blood to the brain. This can cause a brain seizure, leading to death.

Other genes can increase the likelihood of a heart attack by causing structural problems in major blood vessels and in the muscle walls of the heart. For instance, cardiomyopathies, inherited disorders that make the muscle walls either too thick or too thin, result in enlarged hearts with dramatically reduced pumping efficiency. Still other gene defects interfere with the way the body handles salt, thereby bringing on high blood pressure, a notorious heart-attack risk factor: it wears down blood vessels and thus promotes atherosclerosis. An estimated 15 to 20 percent of the U.S. population has a genetically determined sensitivity to salt that is expressed as high blood pressure when they consume too much of it.

Even more leads are pouring in from genetic studies on the enzymes and lipoproteins that determine how effectively the body deals with cholesterol. Geneticists Joseph Goldstein and Michael Brown at the University of Texas Southwestern Medical Center have isolated the "LDL receptor"—the cellular mechanism that keeps harmful LDL cholesterol from accumulating in the body's tissues and bloodstream. Those who lack the gene that allows them to manufacture such receptors develop a life-threatening condition called familial hypercholesteremia (FH), which can result in astronomical levels of cholesterol and early death from heart attack.

And physician Ronald Krauss and his associates at the University of California, Berkeley, have discovered a particle called "small, dense LDL" that they believe is the form of LDL most likely to cause atherosclerosis, because of its ability to penetrate the blood vessel wall. This particle seems to be influenced by a single dominant gene, Krauss says, and he estimates that up to one-third of people over age 40 have that gene and run triple the heart-attack risk of those without it. Moreover, levels of small, dense LDL are closely related to blood levels of triglycerides, another lipoprotein that has itself been proposed as a major risk factor for coronary artery disease.

Research in other areas is also advancing scientists' understanding of the genes behind atherosclerosis. Physician Daniel Steinberg of the University of Southern California in San Diego believes that LDL molecules do their damage when they are oxidized—and that this happens when they are captured by oxygen-like molecules called free radicals. The connection with genetics comes from physician Alan M. Fogelman at UCLA's Atherosclerosis Research Unit, who has shown that when mildly oxidized LDL is injected into mice, troublesome genes similar to those found in humans begin to create harmful proteins; those proteins in turn cause the endothelium to become inflamed. These results suggest that "the inheritance of one or more major genes can determine susceptibility or resistance to the development of the inflammatory component of atherosclerosis," he notes.



INSIDIOUS genes are at the root of "long QT syndrome," a disease that causes heart attacks among children and young adults. An electrocardiogram can identify sufferers: a normal reading, like the one at top, shows an interval of only 400 to 440 milliseconds between the points labeled Q and T. A reading for someone with long QT syndrome, which can lead to an irregular heartbeat, shows an interval of 500 to 600 milliseconds.

THE ROLE OF PSYCHOLOGY

The sophisticated machinery that keeps the heart functioning is strongly influenced by the brain and central nervous system—particularly the sympathetic nervous system, which controls stress responses, and the autonomic nervous system, which makes sure vital organs keep working to maintain life. Thus, an important question driving risk-factor research is how we can use nervous system activity and the psychological forces that so strongly affect it as

CHART: DEB PERUGI DESIGN

bases for determining who is most prone to heart attack.

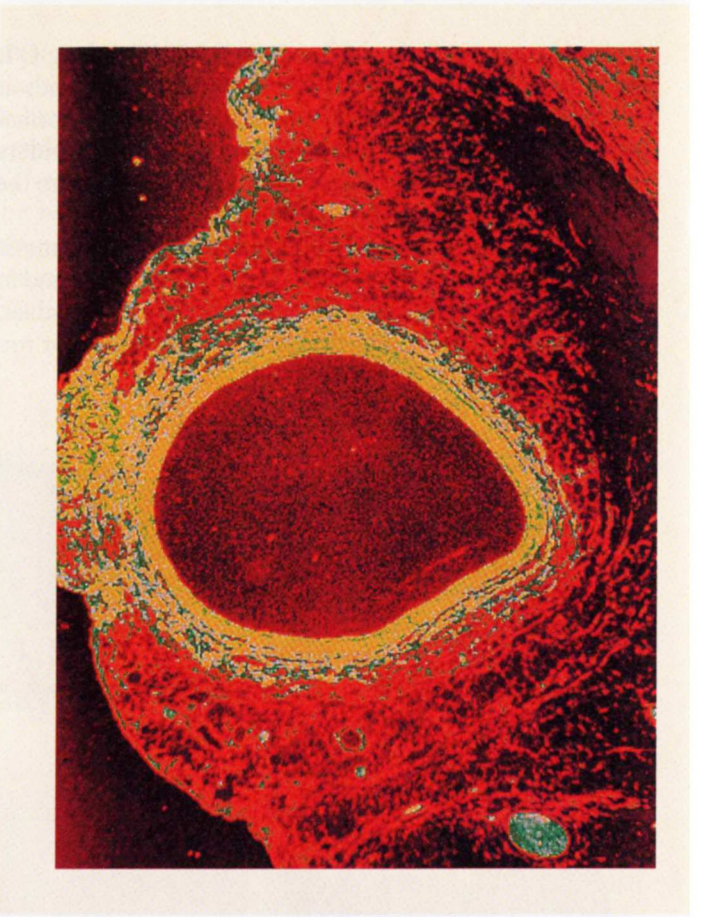
Since researchers have long recognized that a family history of heart attack, heart pain, or other heart problems—particularly in blood relatives before age 60—is important in assessing a patient's risk, it seems reasonable to suggest that specific conditions passed down through the generations deserve a careful look. One issue that is just starting to receive the kind of attention it warrants is the neurological wiring particular individuals may have inherited. Experimental evidence has shown some men and women who may be subject to heart attack apparently have nervous systems set on high. Stress expert and cardiologist Robert Eliot of Phoenix and his colleagues have done pioneering studies measuring heart and blood pressure responses to stressful situations. They have been able to identify some of their subjects as "hot reactors."

Cardiologist Rodman D. Starke, senior staff physician at the American Heart Association, agrees that such individuals may be prone to heart attack, and adds that the people who respond badly to stress are those who "find it wherever [they] go—at home, in the car at red lights, in a line at the supermarket."

An important question is how we can use information about the central nervous system and the psychological forces that affect it to determine who is at risk.

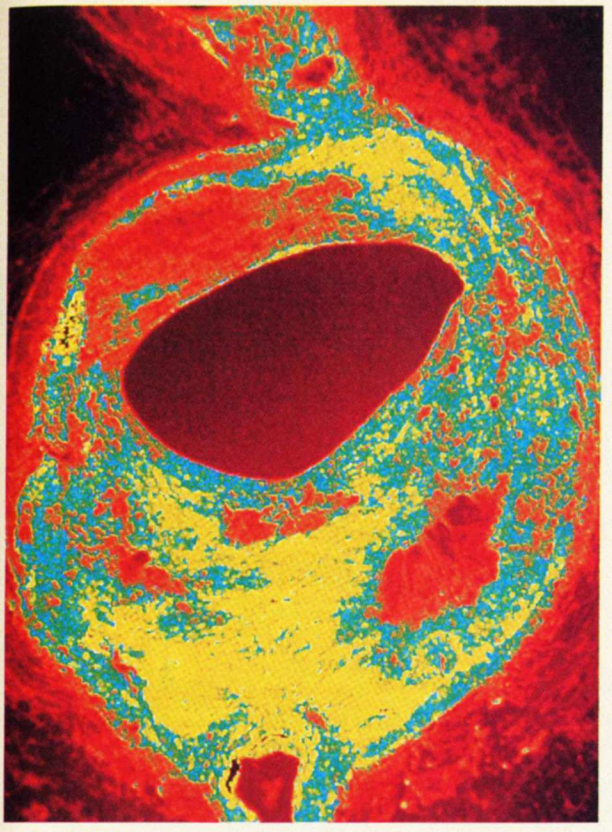
Research by a team from Ohio State University led by psychology professor Tilmer Engebretson suggests that anger, in particular, is a dangerous emotion. Engebretson and his colleagues, who tracked anger characteristics and cholesterol levels in 116 middle-aged male airplane pilots, found large differences between those categorized as "flexible" and those who seemed overwhelmed by their anger and acted in extreme ways. Men judged to have the most trouble with anger registered total cholesterol levels about 40 points higher than normal, and levels of artery-clogging LDLs about 30 points higher than normal.

A good case can be made that depression poses another serious threat to the heart. About 70 percent of people who have had a heart attack suffer depression—often severe depression—in the year afterward, and patients with



severe depression that goes untreated have about twice as many heart attacks during that first year, according to Robert Carney, a psychiatrist at Washington University in St. Louis. "There are now six published studies that show depression increases risk of mortality for patients with coronary disease by several fold," Carney says. How do these deaths occur? Nobody knows for sure, but depressed patients do show elevated levels of sympathetic nervous system activity.

Findings from psychologist John C. Barefoot of Duke University confirm that depression can be hard on the heart. In early 1996, Barefoot's group, reporting on a 27-year study of 513 men and women, noted that individuals who scored high on measures of despair, concentration difficulties, weak motivation, and poor self-esteem in 1964 and 1974 had a 70 percent higher risk of heart attack, as well as a 60 percent higher risk of death, compared with those who had low scores. And S. Leonard Syme, an epidemiologist at the University of California at Berkeley, suspects that social isolation might be a heart-attack risk factor as well. He notes that the theme of "interrupted social ties" seems to play through much of the research on heart disease, including his own studies charting the impact of broken family ties on Japanese men and women who have migrated to Hawaii and then to the San Francisco Bay Area. His subjects experienced a rise in heart attacks and heart attack deaths when they moved into Westernized societies, and he speculates that while some of the increase may be attributable to changes in their diets, psychological factors, including loss of contact with loved ones, may be implicated as well.



NORMAL arteries (far left) allow plenty of room for blood flow. But with atherosclerosis (near left), deposits of smooth muscle cells, calcium, and cholesterol build up. Surprisingly, research now shows that bacterial and viral infection may lead to atherosclerosis.

Finally, job stress could be a crucial factor in determining heart-attack risk. Workplace studies show that employees who feel the most stress are not top executives, as some people might expect, but rather middle managers intent on climbing the corporate ladder. And at the DuPont Corp. in Wilmington, Del., where primary prevention programs and healthier lifestyles are thought to be largely responsible for a decrease in heart attack deaths, corporate medical researchers have discovered that the drop in mortality was about 38 percent in salaried employees with job security but only 18 percent in hourly employees who were more subject to layoffs. Yet another job-stress risk factor for coronary disease might be characterized as situations of "high demand and low control." Studies of telephone operators working at computer terminals and given only so many seconds to look up a phone number show that a significant number reported chest pain during the experience.

Research on the central nervous system has also provided clues about what specific circumstances precipitate heart attack in those who have already been identified as high risk according to traditional criteria. Cardiologist James Muller of the University of Kentucky in Lexington believes certain triggers act through the nervous system of a susceptible person. He and other scientists theorize that pulling one of these triggers sets a specific sequence of events in motion. First, blood pressure surges, constricting arteries. Then a vulnerable plaque breaks open. This plaque rupture is followed rapidly by formation of a blood clot, and the total blocking of blood flow through the artery. The result is a heart attack.

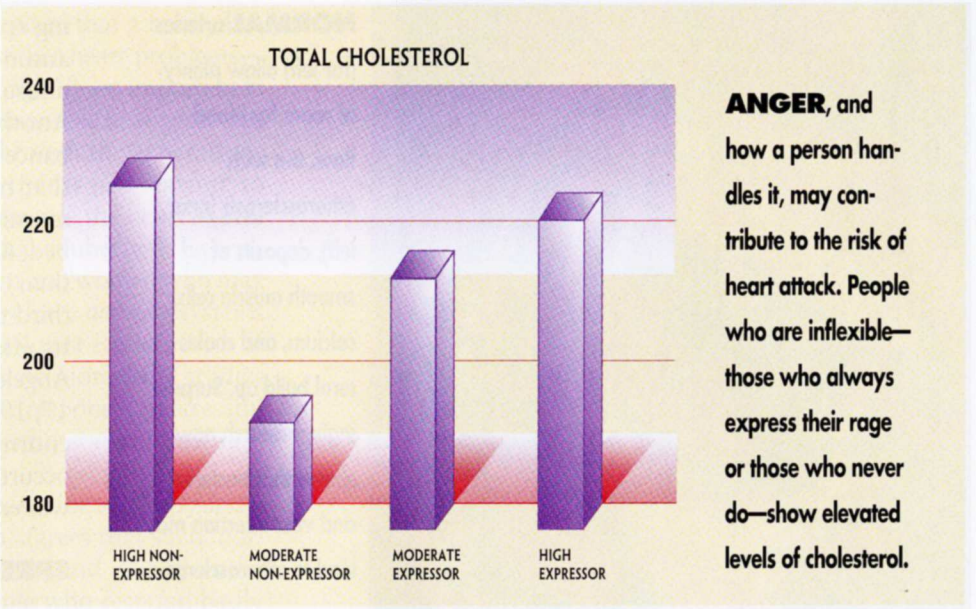
Heavy exertion such as snow shoveling is one trigger, because it stresses the autonomic nervous system and puts an unusual physical workload on the heart. Another potential trigger is any disturbance in bodily rhythms, he says, noting that more heart attacks happen in the morning, particularly after getting out of bed, and that more happen on Monday than on any other day of the week. The third trigger Muller has identified is fear. Its effects surfaced dramatically in Los Angeles during an earthquake on January 17, 1996, he points out. When it hit, "an enormous peak in coronary deaths" occurred, because "the whole population was exposed at the same time."

SPREADING THE WORD

Some of these potential risk factors, such as those related to bacteria and viruses, simply identify individuals who need to be monitored more carefully—such people might do well to watch their cholesterol, weight, and blood pressure more closely. But other potential risk factors could indicate new ways to stave off heart attacks. For example, beta-blocker drugs are beneficial in treating long QT in some children, because they slow down the heart and make the heart muscles less responsive to adrenaline, and thus decrease the possibility that the heart will become unstable. In children on whom these drugs do not work, surgeons have implanted devices that will deliver an electrical shock if the heart needs to regain stability.

The results of acting on good information can be impressive. Roger R. Williams, a cardiologist and genetics researcher at the University of Utah in Salt Lake City, has proven as much. He and more than 20 other physicians interested in the genetics of cholesterol have set out to locate people with the gene for familial hypercholesterolemia, or FH. Toward this end, they have formed a 10-nation network called MED-PED-FH, which stands for "making early diagnosis to prevent early deaths in medical pedigrees with FH." Workers process questionnaires from the blood relatives of known FH victims and track down carriers of the gene. In Utah, such efforts have paid off with the identification of 800 carriers of the FH gene from a base of only 50 known victims. All could be candidates for drugs named statins that Bristol-Myers Squibb, Merck, and Sandoz have developed; based partially on Goldstein and Brown's research, these drugs block a key enzyme involved in cholesterol production.

For people who may be prone to heart attack because they are depressed, drugs such as Prozac and Zoloft and psychologist-led therapy show much promise. Although doctors still lack an economical way to tell whether specific patients are likely to develop high blood pressure if



ANGER, and how a person handles it, may contribute to the risk of heart attack. People who are inflexible—those who always express their rage or those who never do—show elevated levels of cholesterol.

To save patients from untimely death, medical organizations must convince doctors to make use of the latest findings showing who is at risk.

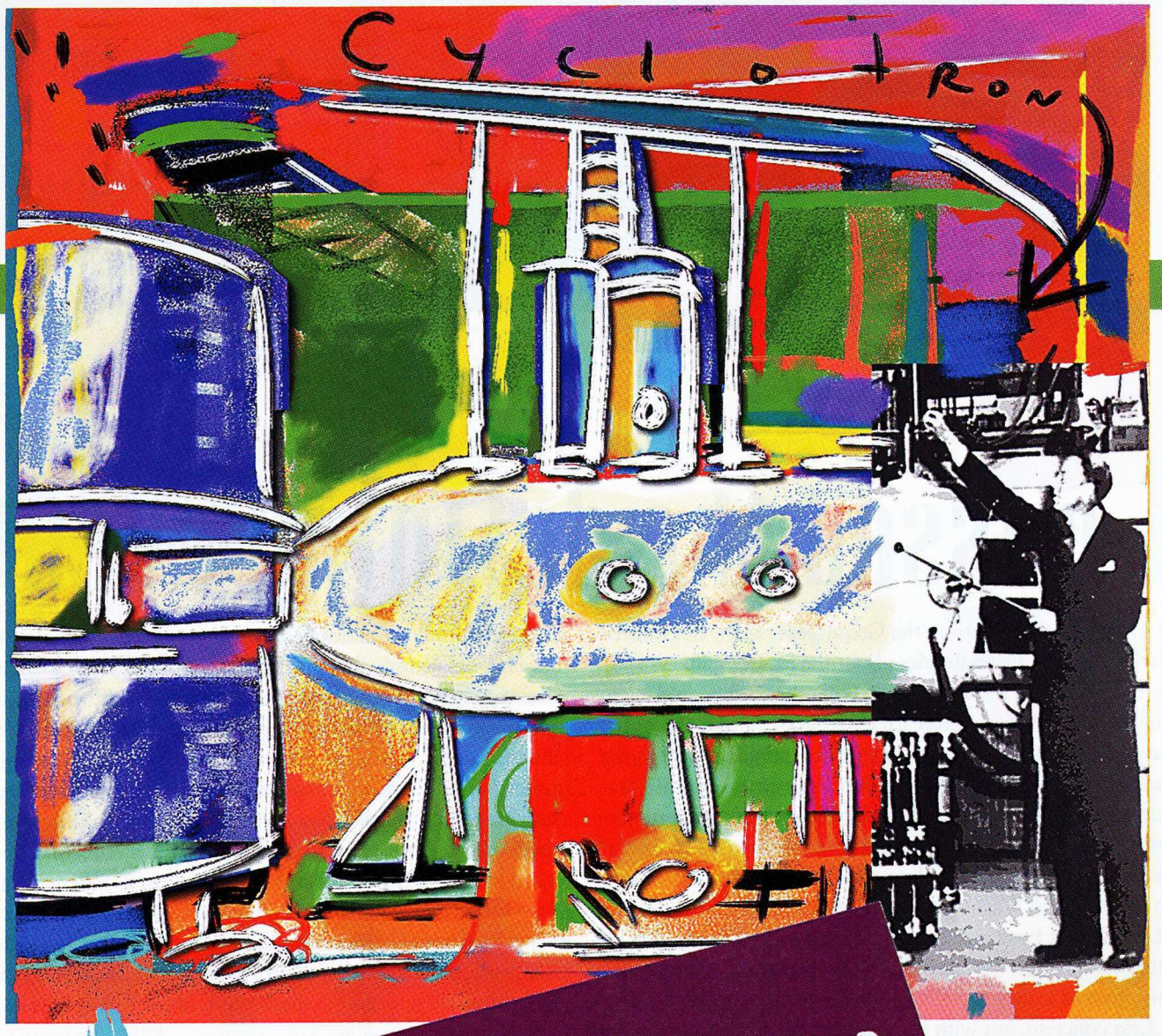
they consume too much salt, discovery of the gene responsible for such sensitivity has spawned a new class of drugs called "angiotensin converting enzyme inhibitors" that help the kidneys handle salt more effectively. And Searle has recently come out with a drug to control blood pressure that is designed to deliver its peak dose in the morning hours, when, as Muller's research on heart-attack triggers has demonstrated, people are particularly vulnerable.

At least three major studies could help pin down some of the new risk factors that have been proposed. The World Health Organization's MONICA project (for "multinational monitoring of trends and determinants in cardiovascular disease") is charting heart attacks and heart-attack deaths at 38 locations in 21 nations, with final results expected by 1998. The Atherosclerosis Risk in Communities study—the one that has already turned up much of the information linking heart attacks to bacterial and viral infection—will also be completed in 1998. And a newer study called Enhancing Recovery from Coronary Heart Disease, sponsored by the National Heart, Lung, and Blood Institute, began in October 1996 to look specifically at loneliness and social isolation as heart-attack risk factors.

But new findings are not enough. In fact, even the new interventions that may grow out of those findings are not enough. The professional organizations that represent doctors in practice—for instance, the American College of Cardiology, the American Heart Association, and the National Heart, Lung, and Blood Institute—must spread the word about the latest research. They need to convince doctors that it is based on sound science and that it will help them deliver better care to their patients.

Such efforts could enable medical workers to save many patients around the world from untimely death or disability. To be sure, more people with established high-risk conditions such as diabetes or high blood pressure need to be identified and convinced to take their medications, follow their diets, keep their appointments, stop smoking, or make other changes in their behavior. And those who have already suffered from heart problems need the kind of rehabilitation and education that could keep their situation from deteriorating. Physician Sidney C. Smith Jr., a recent president of the American Heart Association, reports that only about 30 percent of patients who have had heart attacks or procedures like bypass surgery are being sent on to rehabilitation, and that few are being counseled by their doctors to stop smoking and eat a healthful diet. Still, the importance of ferreting out new heart-attack risk factors cannot be overestimated. Until we know more about the conditions that contribute to heart disease, prevention programs will remain sadly limited. ■

CHART: DEB PERUGI DESIGN FROM TILMER ENGREBRETSON



Brother, can you spare a cyclotron?

BY SIDNEY PERKOWITZ

Everyone knows the government supported construction projects during the Depression, but who recalls the creative ways it furthered scientific research? Lessons from the era could help R&D today. ➤ ➤ ➤ ➤ ➤ ➤ ➤ ➤

ILLUSTRATION BY SUSAN LE VAN

THE WORKS PROGRESS ADMINISTRATION SUPPORTED A BROAD SWATH OF PROJECTS, INCLUDING (LEFT TO RIGHT) LUCILE LLOYD'S WORK ON A MURAL FOR THE CALIFORNIA STATE BUILDING IN LOS ANGELES, EXPERIMENTS USING THE ATOM-SMASHING CYCLOTRON, AND THE CONSTRUCTION OF NEW YORK CITY'S EAST RIVER DRIVE. THE CYCLOTRON'S INVENTOR, NOBEL LAUREATE ERNEST LAWRENCE, IS SHOWN AT FAR RIGHT.

I missed the defining event

of my parents' generation, the Great Depression. But I heard plenty about it, through tales about the jobless selling apples on the street and the songs Woody Guthrie sang. And eventually I found that so large an event leaves other traces for later generations to unearth. Some are tangible, such as the facilities constructed under the Works Progress Administration (the WPA, later called the Work Projects Administration), which President Franklin Roosevelt founded by executive order in 1935 to employ millions of the jobless. If you have flown into Washington's National Airport, driven down Manhattan's East Side Drive, or used any of thousands of other facilities, roads, and buildings, you have encountered this physical legacy.

Less concrete, but with its own kind of permanence, is the cultural legacy of the WPA, which employed artists along with the legions of blue-collar workers needed for construction jobs. Theatrical productions like Orson Welles's *Macbeth*; murals that decorated (some said blemished) the New York Public Library and other buildings; art prints and posters; American travel guides—these and more came out of the WPA Federal Art, Theatre, Music, and Writers' projects. And the WPA supported artists who would later do important work. Richard Wright began *Native Son* in time allowed for creative writing apart from his WPA assignment; Jackson Pollock started developing his abstract style while receiving a WPA paycheck.

Not so well known is the legacy left by the scientists and engineers who conducted research with WPA help. It too includes famous practitioners and classic works: research by the likes of Glenn Seaborg, who won a Nobel Prize in 1951 for discovering plutonium and other atomic elements beyond uranium; significant compilations of data such as the MIT Wavelength Tables, which became a Rosetta stone for scientific research; and experiments conducted on atom-smashing machines, the Big Science of the time. Not only do these moments in American scientific culture deserve recollection, but a look at WPA science, as well as some of its other endeavors, offers lessons for today. Although we 1997-model Americans have it far better than did the Depression generation, many scientists also operate in a climate of scarcity—layoffs and shrinking budgets—reminiscent of those earlier days.

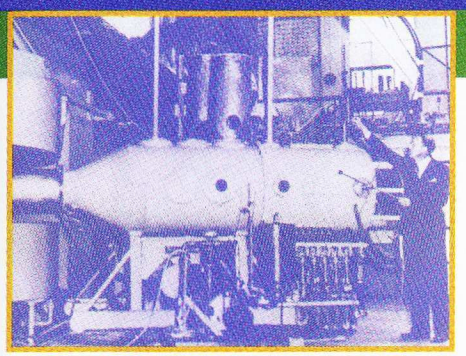
SIDNEY PERKOWITZ, Charles Howard Candler professor of physics at Emory University, has seen federal funding come and go as a researcher and while serving with the Southeastern Universities Research Association. His latest book is Empire of Light *(Henry Holt, 1996). He can be reached at physp@emory.edu.*

Keeping the Science Gears Turning

Federally supported science was not utterly new in the 1930s. The public had long valued and paid for agricultural research; military technology received funding during the Civil War and World War I; and since 1901 the government had maintained the National Bureau of Standards (now the National Institute of Standards and Technology). But this support did not extend to broad-based, long-term, nondirected research, the kind professors perform at universities. State funds supported such efforts at leading state universities, but most funding for pure research came from private foundations. Corporations such as the American Telephone and Telegraph Co. funded applied research in their laboratories, figuring the work would lead to profitable new products.

When the Depression decimated these research funds, a group of leading scientists, headed by Karl T. Compton, then president of MIT, asked for a federal investment of $75 million over five years—at the time an enormous commitment—

PHOTOS: CORBIS-BETTMANN



mostly for university research. The federal government rejected the request because the scientists were unwilling to specify how the money would be spent; instead, the government asked WPA to contribute to science and engineering research by paying for the assistants and support personnel needed to work with academic scientists. In fact, the WPA put nine-tenths of its science budget into salaries for relatively untrained people before the agency shut down in 1943. By then federal dollars were flowing to science as part of the war effort, most notably through the Manhattan Project.

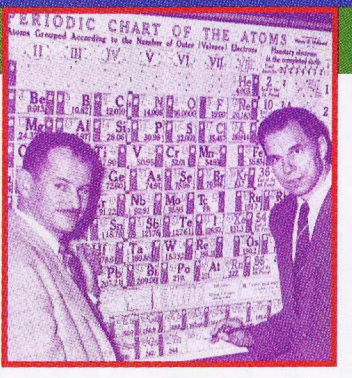
Although WPA support for science amounted to only 3 percent of the agency's overall funding, the funds were 10 times greater than those for either the Art or Writers' projects. And a few percent of a budget of some $14 billion over the lifetime of the WPA was enough to influence a great deal of research. The *WPA Index of Research Projects* through mid-1939 lists 60 efforts in mathematics, physics, chemistry, and astronomy, more than 300 in biomedical science, and hundreds more in other sciences and technology. Much of this research was of publishable quality: two-thirds of the projects in physical science, for instance, were reported in journals like the *Physical Review*, which is still preeminent.

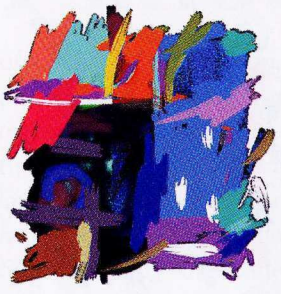
Familiar names appear on some of these articles, including those of three outstanding researchers at the University of California, Berkeley, who operated on the cutting edge of nuclear physics with the assistance of WPA financing for their staff. Glenn Seaborg bombarded atomic nuclei with subatomic particles to transform one kind of nucleus into another, work related to his Nobel prize–winning research. Luis Alvarez, who was to win the 1968 Nobel Prize in physics for his method of detecting elementary particles, explored how an atomic nucleus captures its surrounding electrons, a process that illuminates the theory of anti-matter. Ernest Lawrence won the 1939 Nobel Prize in physics for his invention in 1932 of the cyclotron, the first truly powerful atom-smasher. In two WPA-supported projects, Lawrence used the device to make neutrons, which had been discovered in 1932, and tested their power to destroy tumors.

Other projects led to compilations of archival data with enormous scientific impact. The MIT Wavelength Tables did nothing less than determine the characteristic light emitted by each element in gaseous form and at high temperatures—hydrogen, oxygen, and the 100-odd others that make up the universe. For example, hydrogen emits ultraviolet radiation and mercury a red glow under those conditions. Knowing the wavelengths of the light allows scientists to unequivocally identify the matter that emitted it, no matter how far away. What we know of the birth, death, and constitution of stars comes from analyzing their light.

Similarly, the WPA Mathematics Tables Project, conducted in collaboration with the Bureau of Standards, extended the quantita-

Rather than fund scientists directly, the WPA mostly paid for the assistants and support personnel who worked with them.





Scientists should continue seeking and receiving federal money but can also try to replace dollars with ingenuity.

tive language that scientists use to describe the world. Over centuries of analysis, certain functions have proven essential to the mathematical vocabulary. For example, the recurring peaks and valleys of the sine wave describe the repetitive vibrations common in nature that form waves of water, sound, and light. Other examples include the exponential function, which describes extremely rapid physical change, and Legendre functions, named for the eighteenth-century French mathematician who first explored them, which describe electric fields and quantum behavior.

In 1938, when the mathematics project began, its aim was to calculate these useful functions and publish the results in tabular form. A contemporary article characterizes the project's computational facility as the largest ever established. It used some 150 electrically powered machines, which added and subtracted numbers the same way an automobile odometer works, with rotating gears whose positions represent numbers and interlock so that results can "carry" from one column to the next. Some 250 WPA-supported staff worked among the slowly churning electromechanical monsters, with their characteristic "chinga-ching" sounds. The employees, who were known as "computers," checked the results and transferred them from one machine to another, since no single machine could calculate the functions all by itself. The effort continued from 9 a. m. to midnight five days a week, year after year. By 1942, the project had published 12 volumes of tables and had also performed secret military calculations.

Today, of course, printed mathematical tables no longer enjoy brisk sales; people can instantly determine functions using calculators and electronic computers. But during the WPA era—before 1944, when Harvard University researchers built the electromechanical Mark I computer, which followed stored instructions, and before University of Pennsylvania scientists completed the first programmable electronic digital computer in 1946—the development of the tables promised a significant boon to science.

PhDs Aren't Everything

The Mathematics Table Project and other WPA research efforts remind us that although science needs people with doctorates, it also needs those trained less intensively. If we make earning a doctorate the only worthy goal of scientific education, we may not best serve the long-term interests of science and those who are drawn to it. The issue is relevant now because we may be producing too many PhDs in the sciences. In physics, for instance, we annually turn out 1,400 new doctorates for 700 positions. The WPA focus on support staff for scientists suggests a way out of this bind. People with good technical, bachelor's, and master's degrees—not just those with doctoral degrees—also play important roles in launching a Hubble Space Telescope or turning an idea into a product.

We should avoid making hasty decisions

ALSO BENEFITING FROM WPA SUPPORT WERE (LEFT TO RIGHT) ACTOR AND DIRECTOR ORSON WELLES, NOBEL PRIZE-WINNING PHYSICIST GLEN SEABORG (SHOWN RIGHT OF FELLOW NOBELIST EDWIN MCMILLAN), AUTHOR RICHARD WRIGHT, AND PHYSICIST AND NOBEL LAUREATE LUIS ALVAREZ.

about the numbers of PhDs needed, since employment prospects can change over the years necessary to produce a scientist with a doctorate. But the more choices we can give students during this uncertain funding period, the more they—and science—can succeed. One way to achieve such flexibility is to offer a variety of degrees.

The Physics Department at Emory University, where I teach, offers both a traditional BS degree and a BA—the latter requires fewer physics courses and is intended for those who want to pursue directions other than a graduate physics program. We also offer a BS in applied physics, representing a move away from the idea that every student must study advanced quantum mechanics. This curriculum trades some standard courses in theory for others in optics, computing, and electronics, preparing students for either immediate employment or graduate work in those fields. The applied track has become our department's most popular undergraduate program.

Graduate education can also be made more flexible by offering highly specialized master's degrees that are not just traditional low-value whistle-stops along the track to a doctorate but provide substantial training in, say, growing semiconductor materials. And if graduate education were to include more practice in writing, speaking, teaching, and managing research, it would give students additional abilities to help them keep up with a changing job market.

Another lesson from the WPA era is that, although science needs proper facilities, a healthy scientific enterprise can continue even in the face of government cutbacks in funding for equipment. The WPA paid for people instead. Scientists such as Lawrence, Alvarez, and Seaborg made do with existing facilities or exercised their ingenuity to find other sources of support, such as the nonprofit Research Corporation. (Since 1912, this nonprofit foundation has applied the proceeds from an invention that reduced industrial air pollution for the "advancement of technical and scientific investigation"—varied research that has, in fact, included some of my work.) Lawrence also raised about $2 million from the Rockefeller Foundation and other nongovernment donors to begin building, in 1940, the world's biggest cyclotron, then the pinnacle of elementary particle research.

Today private funding still has its impact. For instance, the W. M. Keck Foundation has given $140 million to build an observatory housing an immense telescope on the extinct Mauna Kea volcano in Hawaii. But the costs of many kinds of equipment have outstripped the reserves of private support—and sometimes even government aid. In 1993, the Superconducting Supercollider, descended from the cyclotron, had already cost $2 billion when the federal government abandoned preliminary construction in the Texas desert rather than spend another $9 billion.

While scientists should continue seeking and receiving federal money to support needed equipment or upgrades of valuable but aging facilities, they can also try to replace dollars with ingenuity, as NASA scientists and engineers have already done. For example, they have simplified the large Cassini spacecraft expected to be launched this October to examine Saturn and its environs. One change eliminated a rotating platform that was to hold astronomical instruments. Without the platform the space vehicle must alternate between gathering data and turning its body so its antenna faces the earth, which enables the craft to send home the information. Still, the device can harvest a broad range of information. Such modifications have reduced costs of the Cassini mission by one-fifth.

And in elementary particle physics, costs will be shaved from the next huge accelerator, the Large Hadron Collider, because it will be built within an existing tunnel some 17 miles around. And because that tunnel is located at the European Laboratory for Particle Physics (known as CERN), the international agency for particle research that straddles the Swiss-French border, support should be readily available from sev-

eral nations. Researchers are also beginning to examine novel and potentially much cheaper table-top-size, laser-based techniques that may someday serve to raise elementary particles to high energies.

As scientists face funding realities, they also need to confront an inevitable corollary: if science needs public dollars, it must win public acceptance. That means showing that the work is important to society. The WPA offers a lesson here as well, but through its artistic rather than scientific activities. Poring over WPA reports, I found no efforts to present science to the public, although scientific breakthroughs did attract popular attention. But the WPA made a point of bringing its artistic activities to people. The Music Project invited Aaron Copland and Virgil Thomson to conduct public concerts; the Art Project attempted to beautify the civic world. These efforts were not meant to turn most citizens into painters and composers but to show that culture is, or should be, part of our lives.

In 1997, science too is part of our lives. It has become an economic engine. Yet its practitioners often fail to impart to the public a sense of how science works and what it has accomplished; they fail to awaken the sense of wonder that occurs when we gain insights into the human mind or find planets beyond our solar system.

Even in the college classroom, where we are supposed to be reaching people, we often do a poor job. Few science courses and textbooks aim at non-majors. I teach astronomy to nonscientists and find that most available texts cannot bear to omit any facts whatsoever. The poor students, who have no plans to become professional astronomers, lose sight of beautiful ideas in thickets of detail. If science were more accessible, helping students to understand the natural world and their own civilization, it would yield better-informed citizens who might listen carefully when scientists ask for funding.

In the 1930s and '40s the massive WPA effort, including its science program, created jobs and thus helped hold together an unraveling social fabric and give people hope. Only if scientists understand the realities of the 1990s—only if they appreciate that science is deeply rooted in a society and an economy in good times and bad—and they respond appropriately, will society support them with a similar powerful conviction.

A Particular Passion

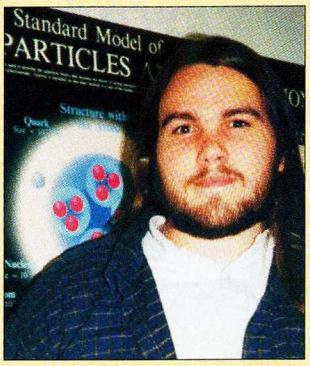
BY JEFF BOWERS

THE Superconducting Supercollider was to be the most powerful particle accelerator in the world. The 53-mile underground tunnel, lined with 11,000 superconducting magnets, would accelerate two beams of protons in opposite directions around a gigantic ring, slamming the beams together to create a spectacular fireworks display of subatomic particles. Physicists expected that by mimicking the conditions thought to exist in the primordial plasma of the early universe, the supercollider would reveal new and exotic species of particles, thereby providing significant insight into the fundamental structure of matter.

During this exciting period, I began studying introductory physics in high school. Caught up in the enthusiasm of the time, I became enraptured with the field. I was first exposed to modern physics through Stephen Hawking's remarkable bestseller *A Brief History of Time*. Hawking's straightforward description of the frontiers of particle physics left an indelible impression. In stark contrast to the familiar realm of classical mechanics, the world of subatomic phenomena seemed counterintuitive and of course wholly unfamiliar. I vowed then to understand properly this domain of physical phenomena.

You can imagine my excitement upon entering MIT as a freshman in September 1993, enchanted by the prospect of performing future research in that field. You might also imagine my profound disappointment one month later when, Congress unceremoniously scrapped the supercollider project. Construction of the 16,000-acre facility was halted, machinery was salvaged at auction, and the half-completed underground tunnel was refilled with dirt. The extraordinary machine, once heralded as the flagship for the world's high-energy physics program, was reduced to a barren plot of broken earth in Waxahachie, Texas.

Although the project's termination was not in itself a



devastating blow, many high-energy physicists perceived it as a symptom of diminishing U.S. support for the entire field of research. On the brink of new achievement, the particle-physics community had choked on the end of its leash, held back by a Congress that held little esteem for basic research.

Some time after the supercollider's demise, I visited a particle physicist at MIT and noticed on his office wall a poster that vividly demonstrated the response of the physics community to the recent news. The poster featured a large graph on which time was labeled on the horizontal axis from 2000 BC to the present, with a thick red line representing the "accumulated knowledge" of physics. After the Renaissance, the red line's slope increased exponentially, leaping incredibly in the twentieth century and seeming to approach infinity in the 1990s—before abruptly breaking. A prominent jagged edge was labeled "The Death of the Superconducting Supercollider."

Students and faculty alike became exceedingly grim about the prospects for new research and new careers in particle physics. Professors suggested that I concentrate on solid-state, condensed matter, or atomic and molecular physics, so that I might find a job in industry or defense. Many recent graduates resorted to semipermanent postdoctoral fellowships, previously considered only stepping-stones to tenure-track positions. Some graduates even left the field, applying their analytical skills to areas such as finance theory on Wall Street or cost-benefit analysis for consulting firms. Suitably disturbed by such stories, I decided to pursue a second degree along with my physics work, in the more financially lucrative field of computer engineering. For a time I relegated my interest in particle physics to a "hobby."

But I soon found that my "hobby" consistently challenged and interested me more than my principal field of study. Although I was competent, I lacked the spirit or enthusiasm to pursue computer engineering as a lifelong occupation. Engineering emphasizes the practical aspects of constructing complex systems—work I considered banal compared with the task of a particle physicist. The grand challenge of that field is to reduce the entire structure of the universe to a simple set of absolute physical laws describing the fundamental nature of matter.

Many have criticized particle physics for that exact goal, in fact, claiming it has no relevance to everyday phenomena. Such observers fail to realize that by neglecting pure or abstract research, we imperil long-term technological development. When Michael Faraday presented his experiments in electricity and magnetism to Queen Victoria, she reportedly asked him, "What good is electricity?," to which he replied, "Madam, what good is a baby?" A presumption that pure research will never yield practical results is naive and shortsighted.

Yet for the sake of argument, even if particle physics never proves "useful," the pursuit of knowledge itself makes the task worthy. The ancient Greek philosophers understood this to the extent that they were almost contemptuous of practical knowledge, favoring the abstract over the concrete. During the Age of Reason in the 1600-1700s, scientists continued to study physics primarily for its own sake; this pursuit of knowledge was ennobled by a perception that the laws of physics were a manifestation of God's order. Not until after the advent of the industrial age did the study of physics become a more practical occupation, a means for developing new technology. The world wars of the twentieth century firmly established that physics could have practical applications, most conspicuously in the development of the atomic bomb.

Almost four years after the supercollider was canceled, and despite a persistent climate of pessimism about the field, I have decided to pursue a career in particle physics. Egotism or naive idealism might be blamed, but I prefer to ascribe my decision to stubborn optimism. For the same reason a poet writes poems, I will continue to study this field: not because it is practical but because it is important. Making a living may not be easy, but doing something I dislike will mean, for all intents and purposes, not living at all. The death of the superconducting supercollider, though unfortunate, will not end future research in particle physics, and I intend to contribute to that work.■

JEFF BOWERS expects to receive baccalaureate degrees in both physics and electrical engineering, and a master's degree in the latter, next spring. He plans to pursue a PhD in theoretical partical physics. His e-mail address is jbowers@mit.edu.

PHOTO OF JEFF BOWERS: MEGAN L. HEPLER

Winning the War

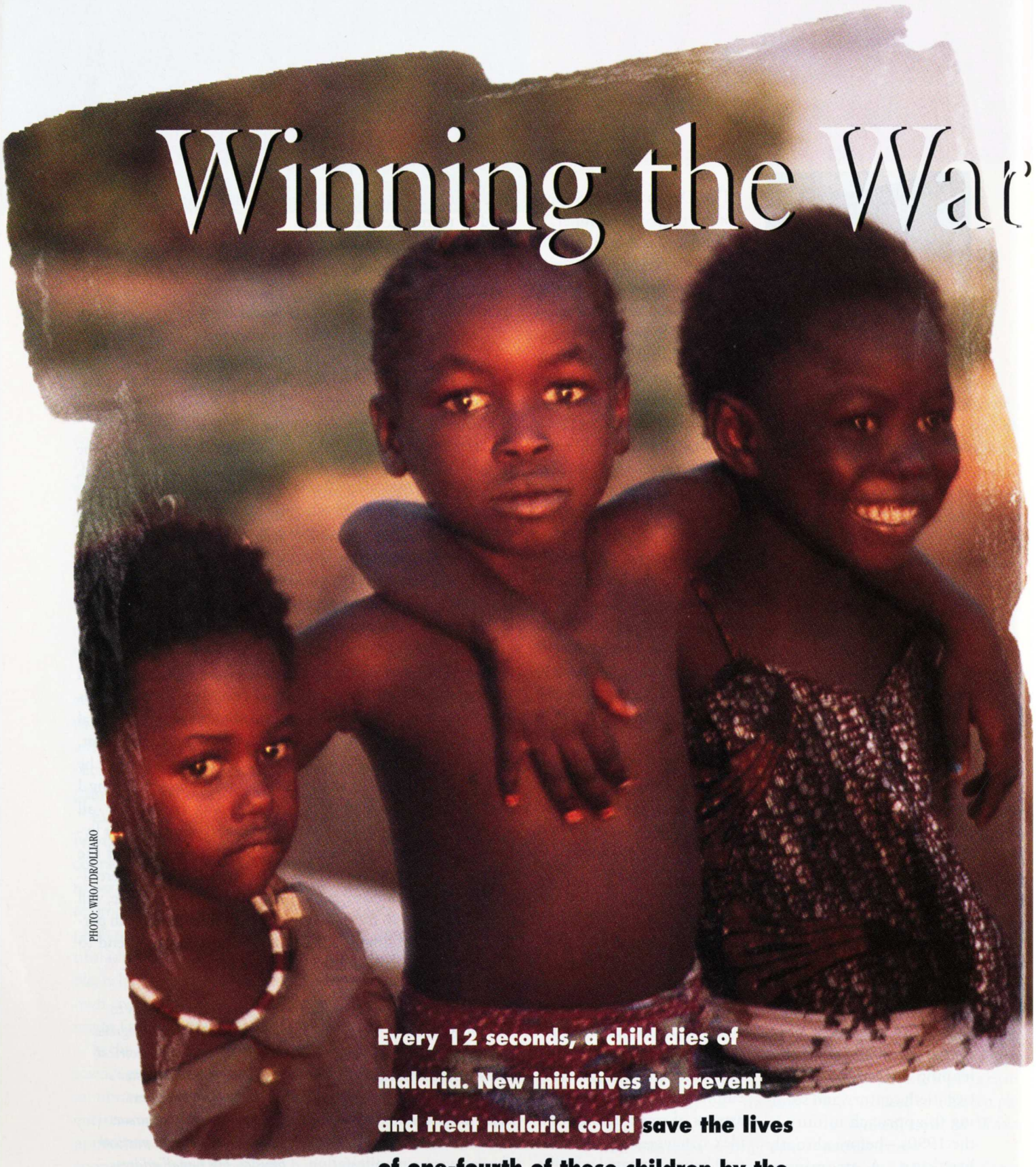


PHOTO: WHO/TDR/OLLIARO

Every 12 seconds, a child dies of malaria. New initiatives to prevent and treat malaria could save the lives of one-fourth of these children by the turn of the century.

Against Malaria

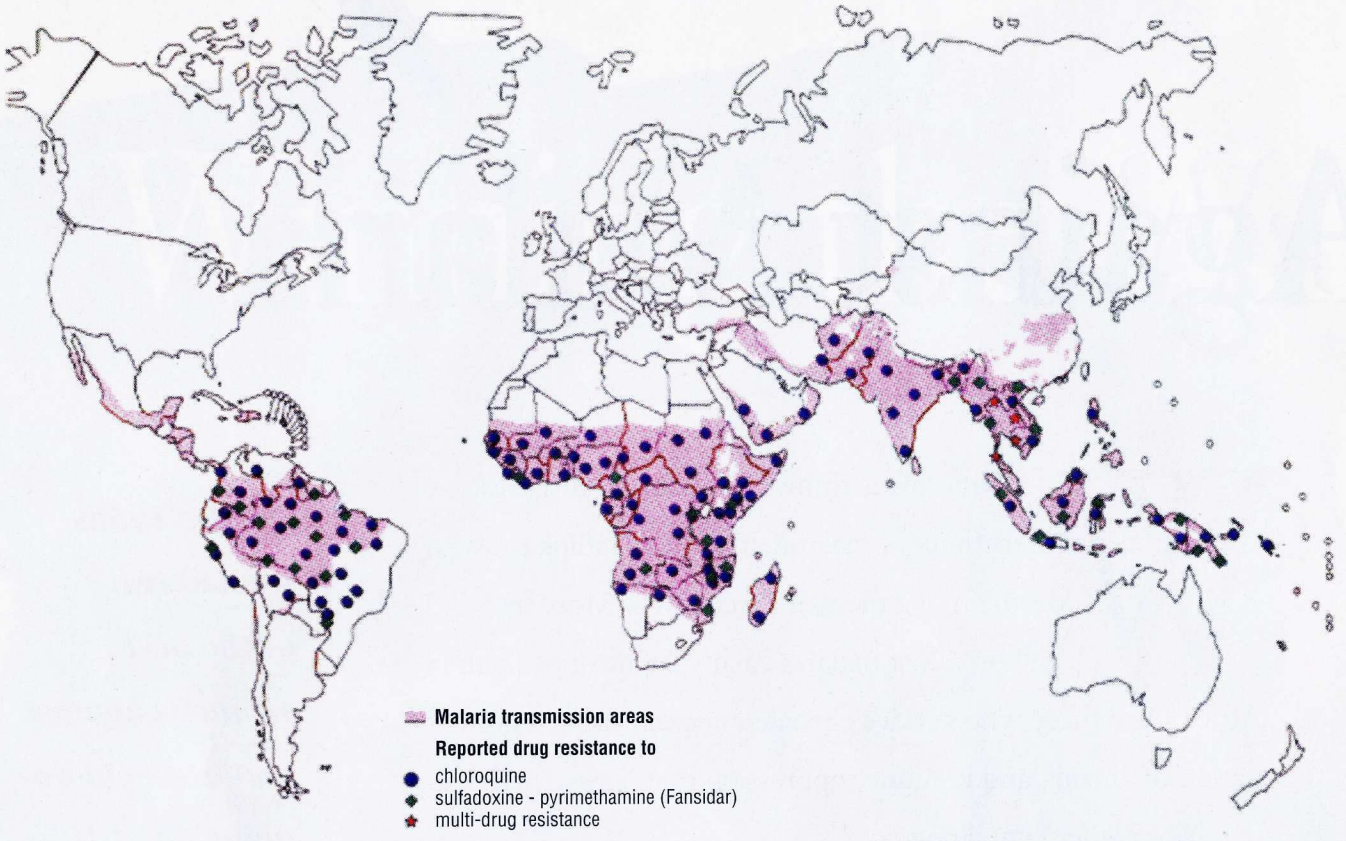
WHEN Americans think of childhood diseases, we rarely think of malaria. Yet it is a leading cause of death among the world's children. More than 2.5 million die of malaria each year, most of them in Africa. And those who survive chronic infection suffer a combination of anemia and immune suppression that leaves them vulnerable to other fatal illnesses.

Among adults living in areas of high transmission, malaria is best thought of as a chronic, debilitating illness that robs its victims of years of productivity. A single mosquito bite can transmit one of the four parasites that cause malaria, setting in motion bouts of fever, chills, and nausea that can recur for weeks. And in some areas, people receive as many as 300 infective bites per year. According to a 1993 World Bank report, malaria represents a global public health burden second only to tuberculosis among infectious diseases. In sub-Saharan Africa, where most cases of malaria and nearly all malaria-related deaths occur, more years of life are lost to malaria than to any other disease.

BY DYANN F. WIRTH AND JACQUELINE CATTANI

In the 1950s, we had two of the best weapons against malaria—chloroquine and DDT—yet we failed to defeat it. Now, as the threat of untreatable disease looms, we have a second chance.

THE SPREAD OF DRUG-RESISTANT MALARIA



DESPITE MASSIVE EFFORTS TO ERADICATE THE disease in the 1950s and early 1960s, there is more human malaria in the world today than at any other time in history. More than 500 million people are infected with malaria worldwide; one fourth of the world's population is at risk for infection. And the risk is rising as environmental changes and large-scale migration bring people and mosquitoes together and as parasites develop resistance to successive generations of drugs.

Malaria has confounded some of the best minds of this century. A hundred years after the discovery that mosquitoes transmit malaria, we still do not know enough about the disease to defeat it permanently. But we do have the tools to limit its spread and dramatically reduce the rate at which children are dying. Our goals should be to reduce childhood mortality from malaria by at least one fourth before the turn of the century, by half in its first decade, and by more than 90 percent in its second decade. By reexamining both the successes and the failures of the past, we can develop a more effective, comprehensive public health strategy to contain and control this lethal opponent.

DYANN F. WIRTH is professor of molecular parasitology in the Department of Tropical Public Health at the Harvard School of Public Health. She also chairs the Committee on the Chemotherapy of Malaria for the U.N. Development Programme/World Health Organization/World Bank Special Programme for Research and Training in Tropical Diseases. JACQUELINE CATTANI is manager of the Task Force on Insecticide-Impregnated Bednets and Other Materials, and the Task Force on Integrated Management of the Sick Child, for the same organization.

Learning from Failure

Renewed interest in malaria at home and abroad makes this a politically opportune time for new initiatives. Articles in both the popular press and scientific journals have called attention to the looming crisis posed by the disease. In January 1997, malaria experts from 35 countries and representatives from the major agencies that fund malaria research convened at an international conference to address the spread of the disease in Africa. And the World Health Assembly, the governing body of the World Health Organization (WHO), passed a resolution calling on member states to renew their political commitment to malaria control and to guarantee sufficient funding, staff, and other resources to sustain this effort.

This is not the first time that public and private agencies have geared up to assault the disease. In the 1950s, WHO, the United Nations International Children's Emergency Fund (UNICEF), and the U.N. Food and Agriculture Organization enthusiastically declared that the time was right to eliminate malaria as a public health problem throughout the world. The malaria eradication programs they sponsored relied on a combination of prevention—spraying with the

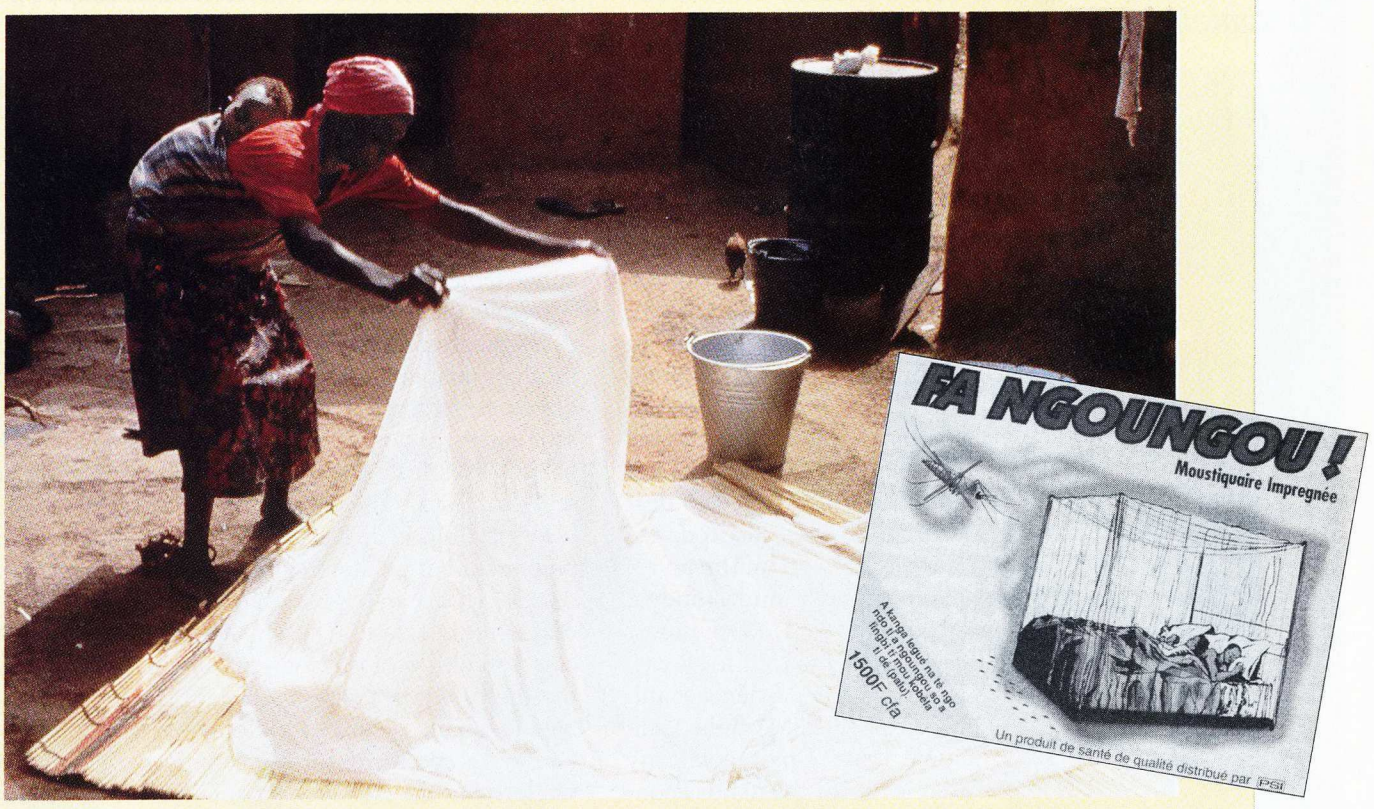
MAP BY DEB PERUGI DESIGN

insecticide DDT—and early identification and treatment of infected individuals, deploying an arsenal of new antimalarial drugs, the best known of which was chloroquine. (Although WHO described this effort as a global eradication campaign, sub-Saharan Africa was not included in the early phases, probably because high transmission rates, the lack of administrative and financial resources, and the logistical problems of reaching rural areas were so daunting. Presumably, the plan was to include Africa after success had been demonstrated elsewhere.)

Despite its initial promise, the DDT campaign backfired. Programs in many malaria-endemic countries were unable to sustain the level of thoroughness and efficiency required to make residual insecticide spraying effective. The result was inadequate or erratic coverage. Mosquitoes that survived low doses of insecticide reproduced, creating populations of insecticide-resistant, malaria-carrying pests. In response to erratic spraying, mosquitoes simply changed their behavior—for instance, they stopped settling on the walls of houses that had been sprayed and moved to nearby vegetation that hadn't.

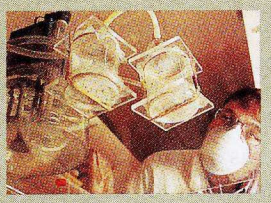
Where the malaria eradication program worked, it soon became a victim of its own success. As the incidence of malaria became negligible in these areas, international organizations downgraded the disease as a priority health issue; at the national level, politicians and government agencies withdrew their support. The result was a dramatic resurgence of infection. In Sri Lanka, for instance, the incidence of malaria reached its lowest point in 1963, when 17 cases were reported. But by 1969, the number of registered cases had shot back up to more than half a million. Today Sri Lanka, like most other malarious countries, is still struggling to control the disease and has abandoned the goal of eradication. Overall, the eradication campaign showed little result outside the United States, Europe, and some parts of northern Africa.

Compounding the political failure of these early efforts was the emergence of drug resistance. As early as 1960, chloroquine-resistant strains of *Plasmodium falciparum*, the parasite that causes the most deadly form of malaria in humans, began to spread in Southeast Asia and South America. In Southeast Asia, resistance to second-generation drugs such as Fansidar emerged rapidly after their introduction for treatment of chloroquine-resistant infec-



Health agencies are investigating methods for preventing the spread of malaria. Above, a Ghanaian woman hangs a mosquito net up to dry after soaking it in insecticide. Sleeping under these nets could save the lives of half a million African children each year at very low cost. The World Health Organization is studying ways to promote the nets, such as this poster (inset).

PHOTO: WHO/TDR/HAALAND



An effective vaccine for malaria remains just where it has been for the past 40 years: tantalizingly out of reach.

tions. Resistance to both chloroquine and Fansidar has now spread to Africa and infections with multidrug-resistant *P. falciparum* are now common in many areas where the parasite is endemic.

To the extent that the parasite represents a moving target for drugs and insecticides, no single chemical compound is likely to defeat it. In the 1950s, we had the best weapons against malaria that we've ever had, yet we failed to control the disease. The failure of these early eradication campaigns teaches that multiple strategies —and a sustained commitment of significant resources—are required to solve the problem.

Over the past two decades, however, we have failed to apply that lesson. Indeed, past interventions have done more to eradicate funding for malaria research than they have to eliminate disease. In the initial years of the eradication effort, DDT appeared so promising that international agencies saw little need to study the disease further. Only in 1965, 15 years after the eradication program began, did WHO finally begin to encourage malaria research. The de-emphasis on science combined with a decline in the number of malariologists left countries ill prepared to deal with the crisis we face today.

Research on malaria remains severely underfunded. According to a 1996 report released by the Unit for Policy Research in Science and Medicine (PRISM) of the Wellcome Trust, a private charity that is one of the major sponsors of biomedical research, expenditures for malaria research equal about $42 per death, while expenditures for research on diseases like AIDS, cancer, or asthma are 100 to 1,000 times higher. According to the PRISM report, in 1993 only $84 million was spent on malaria research worldwide. The largest share—more than one-quarter—was devoted solely to vaccine development. Indeed, for decades, the hope of defeating malaria has rested largely on the belief that a vaccine for the disease is just around the corner.

The Puzzle of Partial Immunity

For 40 years, scientists have labored to create a vaccine against malaria, inspired by the success of this approach against smallpox, yellow fever, and polio. However, unlike these other types of infections, malaria induces only partial immunity in those who contract the disease. After multiple bouts of the disease, a person develops enough immunity to prevent severe infection and mortality, but can still become ill. Moreover, even this limited immunity can be maintained only by frequent reinfection. Thus the ideal vaccine—one that could provide full and permanent protection from illness—would have to perform better than natural immunity, an ambitious goal for which there is no precedent. If researchers were to succeed in developing a vaccine that mimics naturally occurring immunity, it could save millions of children's lives. It would not, however, eradicate malaria the way vaccines have eradicated smallpox.

No one knows the mechanism by which people eventually become partially immune to malaria. It may be related to the complexity of the parasite. Recent work has demonstrated that the malaria parasite expresses a repertoire of thousands of surface molecules, or antigens, which change constantly in the course of a single infection. The parasite therefore presents a moving target for the host immune system: by the time the host forms antibodies in response to one antigen, the parasite has already switched to a new one.

Despite these difficulties, scientists have come very close to developing vaccines that work. Their efforts have focused on the three major phases of the parasite life cycle. The first type of vaccine targets the sporozoite, the form in which the parasite enters the host's body, in order to prevent it from establishing infection. A second, known as the Spf66 vaccine, seeks to destroy the parasite only after it has invaded the host's red blood cells—an approach that could establish partial but not full immunity. And the third type targets the oocyst, a stage in the life cycle of the parasite that occurs only in the mosquito. The aim of this so-called altruistic vaccine is to block transmission from human to human via the mosquito. When a mosquito feeds on the blood of a vaccinated human, she ingests not only the parasite but also the antibodies specific to the target antigens. These antibodies will prevent the parasite from developing and multiplying in the mosquito and subsequently being passed on to other humans. This kind of vaccine would not protect the vaccinated person from contracting malaria, but vaccinating enough people in a given area could substantially reduce the number of infective bites residents receive.

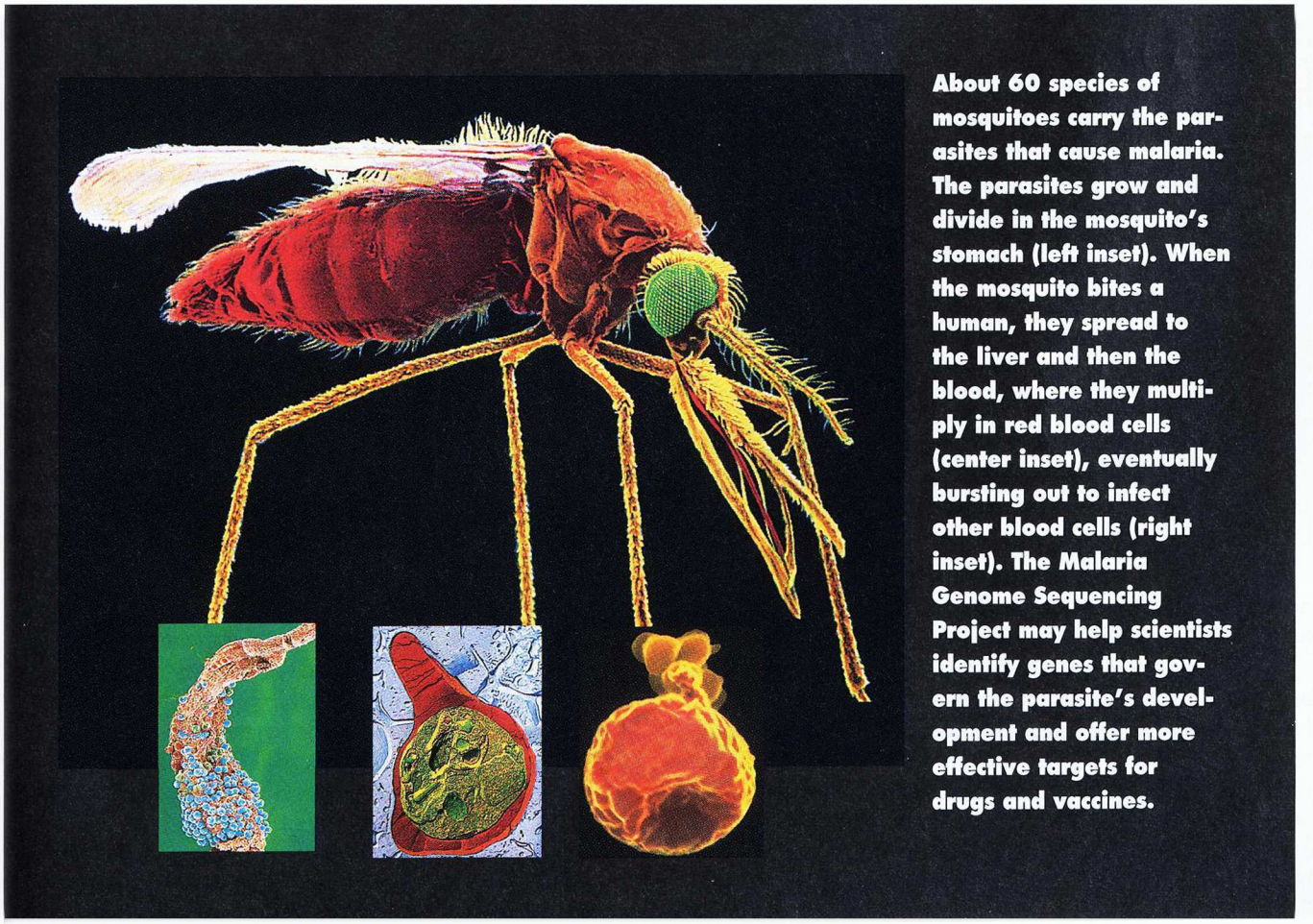
All of these vaccines have shown promising results in animals, but none have worked well in humans. No one knows

PHOTO: PHILIPPE PLAILLY/EURELIOS/SCIENCE PHOTO LIBRARY/PHOTORESEARCHERS INC.

why the parasite operates differently in humans than in animals, and it is not clear when or how we will bridge this gap in our knowledge. A 1991 report on malaria prevention and control by the Institute of Medicine (IOM) summarized the results of the malaria vaccine program with cautious optimism. What we have learned from these initial studies may help in designing the next generation of vaccines, but despite the talents, hopes, and funds devoted to this solution, an effective vaccine for malaria remains exactly where it has been for the past 40 years: tantalizingly out of reach.

Given that an effective vaccine is years if not decades away, and that the best vaccine is likely to have only limited impact in preventing illness, we need to step back and reemphasize both prevention and control. One very promising way to prevent malaria is to use mosquito nets treated with a safe, biodegradable pyrethroid insecticide to protect sleeping children. In the early 1990s, four large-scale, randomized, controlled community trials were conducted in four African countries representing different malaria risks—Burkina Faso, Ghana, Kenya, and the Gambia—to determine the impact of using treated nets on mortality rates of children younger than five. The three-year trials, conducted under the auspices of the U.N. Development Programme (UNDP), WHO, and the World Bank, involved nearly half a million people and 20 research institutes and donors. The results were dramatic: children's deaths from all causes dropped 15 percent in Burkina Faso, 17 percent in Ghana, 33 percent in Kenya, and 25 percent in the Gambia. (An earlier trial in the Gambia cut child mortality 63 percent, but that study was based on 100 percent compliance. The larger studies evaluated the bed nets under real-life conditions, in which compliance ranged from 20 percent to 90 percent.) The magnitude of the reduction in mortality indicates either that malaria is the most important cause of death in the age groups included in the trials or that preventing malaria in young children somehow helps reduce their likelihood of dying from other diseases. These results suggest that if bed nets were made widely available, they could save the lives of up to 500,000 African children each year.

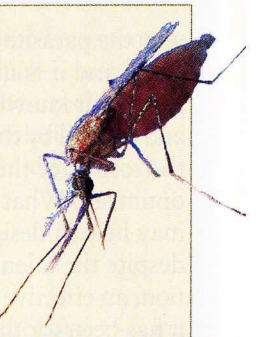
Bed nets are not yet widely available in Africa, and those that are cost between $25 and $30 each—well beyond the reach of the average family. However, locally manufactured nets could cost as little as $5; a year's supply of insecticide costs between 50 cents and $1. Although this sum is still high relative to annual cash income (between $300 and $400 in some regions), there is reason to believe that most African families could afford it. According to WHO, African families spend up to $65 (or one-fifth of their income) each year on antimalarial drugs, mosquito coils, and insect repellents to protect themselves from malaria, with limited effect. If these expenditures could be redirected to reasonably priced insecticide-impregnated bed



About 60 species of mosquitoes carry the parasites that cause malaria. The parasites grow and divide in the mosquito's stomach (left inset). When the mosquito bites a human, they spread to the liver and then the blood, where they multiply in red blood cells (center inset), eventually bursting out to infect other blood cells (right inset). The Malaria Genome Sequencing Project may help scientists identify genes that govern the parasite's development and offer more effective targets for drugs and vaccines.

PHOTOS: TONY BRAIN; LONDON SCHOOL OF HYGIENE; GUPTAL MURTI: ALL FROM SCIENCE PHOTO LIBRARY/PHOTO RESEARCHERS INC.

The War at Home



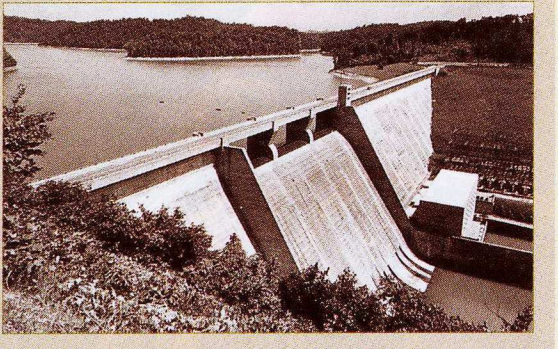
ONE of the few victories in the war against malaria occurred in the United States under the direction of the Tennessee Valley Authority (TVA), the regional development agency created in 1933. At that time, malaria was endemic in the southeastern United States, sapping the health and productivity of the region's residents. To protect its workers as well as ensure the success of its economic development projects, the TVA stepped in to tackle the problem.

The agency's first step was to reduce the population of parasite-carrying mosquitoes in endemic areas. After conducting intensive research on the environmental conditions that foster breeding, the TVA initiated a comprehensive environmental management program. Because mosquitoes lay eggs in or near water—the eggs cannot survive dry—the agency built and maintained an extensive network of drainage ditches to keep water levels in reservoirs low, thereby reducing the area in which mosquitoes could breed. The agency also cleared vegetation from reservoir and river shorelines every summer. (Vegetation contributes to the survival of mosquito larvae by keeping them from being swept away by wind or water currents.)

To limit transmission of the disease, the agency installed window screens in houses and encouraged cattle grazing near reservoirs in order to divert mosquitoes from biting humans. In addition, the TVA initiated an active surveillance program to track and treat suspected cases of malaria, an effort that ultimately led to the establishment of the Centers for Disease Control. The cost of the campaign thus went far beyond the initial high capital investment in preparing the reservoirs. Expenditures on malaria control remained high even as the rate of infection went down. Between 1942 and 1950 the United States spent more than $50 million (about $317 million in 1995 dollars) to control malaria in the South.

What lessons can the TVA campaign provide for malaria control in developing countries? Although malaria eradication is possible under certain circumstances, the approach that worked so well in the American South is not readily transferable to malaria-endemic areas today. In the Tennessee Valley, less than a third of the population was at risk of contracting malaria—and then only during the summer months. Yet enormous financial, human, technical, and infrastructural resources were needed to eliminate malaria in this region. In most of Africa, by contrast, the entire population suffers from malaria, and year-round transmission occurs in many areas. The mosquito species in Africa are the most efficient vectors of all the malaria-carrying mosquitoes, and ecological conditions allow them to thrive. The goal of eradicating malaria through a sustained, comprehensive environmental management and disease surveillance program in these countries is far beyond their financial and institutional reach. ■

—DYANN F. WIRTH AND JACQUELINE CATTANI



To ensure the success of its hydroelectric projects, the Tennessee Valley Authority engineered a successful campaign against malaria.

PHOTO: UPI/CORBIS-BETTMANN

nets, overall family expenditures would actually decline.

WHO is studying ways to promote and distribute insecticide-impregnated bed nets. Like insecticide spraying, distributing bed nets is a long-term commitment, so the key is to ensure that this intervention is sustainable. Rather than simply donating nets, international agencies should support local initiatives or otherwise work with local manufacturers to ensure that bed nets are available to all children at a cost their families can afford. WHO and other international agencies should also fund the research and development of new insecticides that can safely be used on bed nets, since sooner or later vector mosquitoes are likely to become resistant to the pyrethroid insecticides.

From Headache to Coma

Although improvements in prevention are promising, diagnosis and drug treatment remain the mainstay of malaria control worldwide. The keys to effective disease

management are rapid diagnosis and proper treatment. A patient with malaria who comes to a clinic in the morning complaining of a headache may, if untreated, fall into a coma by midafternoon. The longer an episode of malaria goes untreated or ineffectively treated, the higher the mortality rate.

In much of the developing world, however, primary health care systems are unable to provide early diagnosis and treatment. Diagnosing malaria is difficult because the symptoms of infection, particularly early on, are nonspecific—fever, chills, headache. In rural settings, both diagnosis and treatment are often delayed because of the long distances patients must travel to reach a health center. In addition, effective antimalarial drugs may not be available in areas of drug resistance.

Workers at primary health care clinics, where most children with malaria are likely to seek treatment, must be trained to differentiate among illnesses with overlapping symptoms, including pneumonia, measles, malaria, diarrhea, and malnutrition, all of which are leading causes of death in children under five in developing countries. Right now, health workers receive training through a variety of nationally administered programs, each of which focuses on the diagnosis and treatment of a single disease. Health workers are left to develop their own methods for differentiating among diseases and setting priorities for treatment. Focusing on the most apparent problem may cause health workers to overlook an associated, potentially life-threatening condition. A health worker might prescribe an antibiotic for a child with a high fever and rapid breathing in the belief that the child has pneumonia, for instance, without realizing that the child is severely ill with malaria, which shares the same complex of symptoms.

To address this problem, WHO and UNICEF have developed a new approach to diagnosis and treatment called Integrated Management of Childhood Illnesses, which they are implementing on an experimental basis in clinics and health posts in selected districts in Uganda, Tanzania, the Philippines, Vietnam, and Indonesia. The goal is to shift resources and responsibility for training primary health care workers from the national disease-specific programs to the district level and to help health care providers accurately assess the overall needs of the sick child. Health workers are also trained to communicate key information to mothers, thus helping them ensure the health of their children. So far, it appears to be working: preliminary evaluation shows that clinic staff trained under the new approach make more accurate diagnoses and more appropriate referrals for sick children.

Beyond improving diagnosis and referral, we need to ensure the availability of effective treatment. Antimalarial drugs are among the most commonly prescribed drugs in the world, and not only because the disease is so widespread; health workers in endemic areas often overprescribe antimalarials as a result of improper diagnoses. What's more, the few drugs we have are closely related to one another, increasing problems with drug resistance.

Today, resistance is emerging and spreading faster than new drugs can be developed. The newest antimalarials–Malerone, developed by Glaxo-Wellcome, and drugs based on the ancient Chinese herbal remedy artemisinin—are the only drugs that remain effective in areas most plagued by drug resistance, such as Thailand. Parasites resistant to these compounds have already emerged in the laboratory, and health agencies are closely monitoring their emergence in the field.

Given the speed with which parasites are becoming resistant and the length of time required to develop new drugs (even accelerated development takes 5 to 10 years from discovery to clinic), we face a looming crisis: multidrug-resistant malaria with no safe, effective alternatives for treatment. This problem exists today in Southeast Asia and will occur in most other malaria-endemic areas within the next decade.

Despite the obvious urgency of the situation, pharmaceutical companies are not developing new drugs. Over the past decade, the few major pharmaceutical companies that had antimalarial drug discovery and development programs have discontinued or downsized these programs, which were both costly and unprofitable. Today, only a few academic centers and government agencies are working on the discovery of antimalarial drugs; only a few new drugs in the late stages of clinical development remain in the pipeline. (Malerone still awaits final approval in some countries and new formulations of artemisinin are still being tested.)

There is an urgent need to develop novel compounds or compounds that focus on novel pathways--processes essential to the growth and development

One experimental program trains clinic workers to differentiate among illnesses with similar symptoms so children with malaria can receive timely treatment.

PHOTO: WHO/TDR/MARK EDWARDS

To the extent that the malaria parasite represents a moving target for drugs and insecticides, no single chemical compound is likely to defeat it.

of the parasite—that are not the target of current antimalarial drugs. Moreover, researchers must address the problem of drug resistance from the earliest stages of drug development. One strategy to prevent resistant organisms from emerging is to use multiple drugs targeted at different pathways, or at different steps in a single pathway. Another is to identify ways to interfere with the mechanisms that spur mutation or regulate gene expression. A third important target is a protein in the membrane of the parasite that allows the organism to recognize and pump out drugs. Once the protein is expressed, the parasite can resist multiple, unrelated drugs, even those to which it had not previously been exposed. Preventing the expression of this protein or blocking its pumping action is another way to prevent or even reverse resistance.

While previous efforts to develop new drugs and vaccines have been based on empirical observations, new drug development techniques are likely to provide the basis for the next leaps in our knowledge. Techniques such as combinatorial chemistry (creating new compounds by systematically combining sets of chemical groups) and computer-aided drug design (using x-ray crystallography and computer modeling to analyze protein-drug interactions) have accelerated the process of finding new drugs and vaccines for other diseases. We need to apply these tools to malaria before we face the widespread threat of untreatable disease. Since expertise in drug development is concentrated in the private sector, the participation of the pharmaceutical industry—perhaps supported by government funding—is essential to the success of this effort.

Back to Basics

Unfortunately, knowledge of the fundamental biology of the malaria parasite has lagged behind that of many other organisms, largely because of a lack of funding for basic research in this area. Computer-aided drug design or combinatorial chemistry cannot be applied in a vacuum: researchers need to identify the biological processes or specific enzymes that can serve as targets for new drugs or vaccines. To take advantage of these techniques, we need to learn more about the genetic makeup of the organism, its growth and development, and its relationships with the mosquitoes that carry it, the human host, and the environment. For example, we now know that the malaria parasite digests hemoglobin as its source of amino acids. Studying ways to prevent the digestion of hemoglobin could lead to new drugs.

Genetics research promises new insight into mechanisms by which the malaria parasite operates and might be defeated. For instance, techniques for producing parasites that contain a specific modification in a single gene will allow scientists to determine whether specific genes are associated with virulence, drug resistance, or enhanced transmission. This promises to usher in a period of rapid growth in our knowledge of the fundamental processes in the parasite.

A powerful new tool is the Malaria Genome Sequencing Project, a cooperative effort to sequence the genome of *P. falciparum*, sponsored by the Wellcome Trust, the Burroughs Wellcome Fund, the National Institutes for Health, and the U.S. Department of Defense. The goal of this project is to define every gene in the organism by 2000 and, armed with this information, to identify new targets for drug and vaccine development. By comparing gene sequences in the parasite with those of other microorganisms, for instance, we can determine whether enzymes that are used as drug targets in other microorganisms are present in the malaria parasite; if so, they could serve as targets for new antimalarial drugs. Genome scanning techniques, in which scientists study the impact of specific stimuli on the whole array of genes simultaneously, will help scientists discover how different genes interact as the organism responds to new vec-

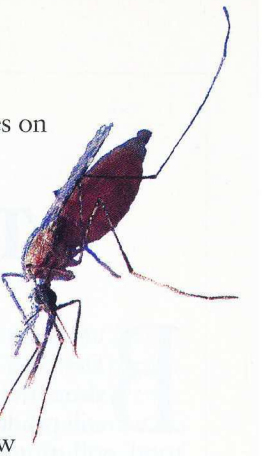
One of the newest antimalarial drugs is derived from the plant Artemisia and is based on an ancient Chinese herbal remedy. Parasites resistant to the new drug have already emerged in the laboratory.

PHOTOS: WHO/TDR/ P.OLLIARO, ANDY CRUMP

tors, drugs, or the host's immune system. The ability to dissect these kinds of complex responses is likely to bring a whole new dimension to our understanding of the parasite.

Information from the genome project may also help scientists develop new DNA-based vaccines. The principle is similar to the approach used in gene therapy: researchers inject into human tissue genes that code for one or more of the parasite's surface proteins. Following the genes' instructions, the human cells manufacture the protein, using the same machinery they use to make human proteins. The immune system recognizes the vaccine-induced protein as foreign and develops protective antibodies. Since DNA-based vaccines can incorporate several genes, they could stimulate the production of antibodies to several antigens at once, thereby strengthening the immune system's defenses as the parasite switches from one antigen to another. However, this alone will not solve the problem of immune evasion: there are simply more variant antigens than a single vaccine can deliver.

Because they are inexpensive and require no refrigeration (a major consideration in the rural areas where malaria is prevalent), DNA-based vacccines provide a promising alternative to traditional vaccines. Using the same surface proteins as those targeted by existing malaria vaccines, scientists are now testing DNA-based vaccines on animals. These trials show promise, but the real test will come in people. The FDA should speed its preliminary approval of DNA-based malaria vaccines so that they can be tested for safety and efficacy in humans.



Today, we have the tools we need to achieve dramatic improvements in prevention, early diagnosis and treatment and, in the long run, to develop new drugs and effective vaccines. But applying them will require a dramatic increase in financial and political support. In endemic countries, governments from the national to the community level must guarantee sustained and stable support for malaria control. At the same time, they will have to exert political pressure on international agencies and the private sector to commit funding and expertise to this disease over the long run. The participation of the private sector is essential and will have to be achieved through some combination of moral pressure and financial incentives. More than money, what it will take to defeat malaria is the political and moral determination to save the lives of millions of children.■

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FORUM

BY MARC ROSS AND TOM WENZEL

The Few. The Failed. The Polluters.

BLAME the customer. That's been Detroit's response when figures show that today's automobiles still produce 50 percent as much total pollution as in the late 1960s, despite regulatory limits that set emissions from individual vehicles 90 to 96 percent lower. The fleet of U.S. cars is still producing half as much pollution as in the pre-regulation era, because people are keeping their cars longer, driving more, and, the carmakers claim, neglecting to maintain their new ones.

We are driving about twice as many miles as before regulations were applied, but that doesn't account for the gap. About half of all automotive emissions come from "high emitters"—vehicles with emission control systems (ECS) that have failed in use. A high emitter produces some 25 times as much pollution as a properly functioning vehicle. About 5–10 percent of all 5-year-old vehicles are high emitters.

ECS failures stem from a variety of causes. A good example is failure of the fuel-injection system—either failure of the injectors themselves, the computer chip that calculates the amount of fuel needed, or the sensors that provide data to the chip, such as on the amount of air flowing to the cylinders. Failure of any of these components results in incomplete combustion and poor performance of the catalytic converter.

Our research shows that ECS failures occur largely in a few vehicle models. Many of these failure-prone models are relatively new—from the early nineties. We have found other models that experience almost no such failures, regardless of any neglect or abuse, for at least nine years. Thus the burden for fixing the problem lies not so much with drivers as with manufacturers.

This model-dependence apparently comes as a surprise to manufacturers and regulators, partly because they receive little feedback when these systems go wrong. Existing tests and surveys turn out to be inadequate for several reasons:

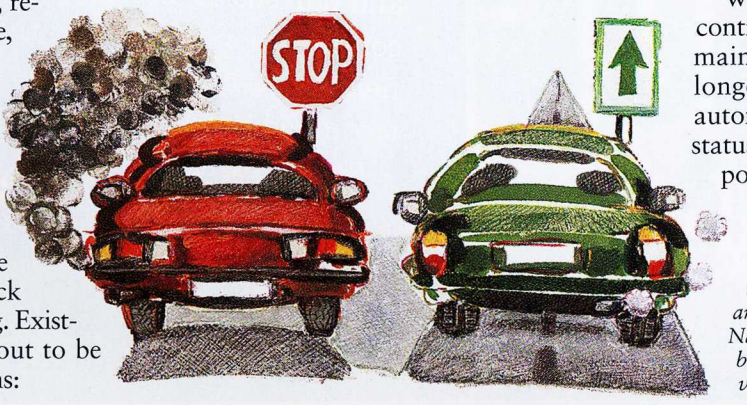
- The standardized emissions test for new vehicles entails aging of individual components in the laboratory rather than subjecting the whole system to the rough and tumble of real-world driving and maintenance, or lack of it.
- The elaborate and expensive "in-use" tests that regulators conduct include only tiny numbers of meticulously maintained vehicles of a given model. Such procedures catch few of the dirty offenders.
- Information from dealers on their attempts to fix emission control systems is haphazard—partly because drivers are often unaware of, or uninterested in correcting, an emissions problem.
- State inspection agencies rarely report failure rates by vehicle model. Plus, many state-administered "smog tests" simply sample emissions from a car while it is idling—despite the fact that cars pollute far more under normal driving conditions.

One solution is for states to undertake even more ambitious inspection and maintenance programs, as recommended by the Environmental Protection Agency. But inspection and repair of millions of vehicles is costly, cumbersome, and often done poorly. Almost no garages have the costly equipment needed to accurately measure emissions from a vehicle that is under power rather than idling. And many believe that repair efforts at thousands of garages are even less effective than the initial inspection. Automakers are installing on-board diagnostics (OBD), which notify a driver when emissions controls have failed, in all 1996 and newer cars. Regulators hope OBD will make state inspection and maintenance programs more effective.

Another approach would focus on identifying the particular vehicle models whose emission control systems are prone to fail. Doing so will require collecting data from hundreds of thousands of vehicles using state testing results, OBD, or roadside emission sensors. Carmakers report that OBD is already identifying manufacturing flaws in particular vehicles before they reach the dealers' showrooms.

Unfortunately, there is no formal mechanism in place to make data from OBDs or from state-run emissions testing programs available to the public. Creating such a mechanism—and analyzing the data to determine which models fail—might motivate car manufacturers to create more durable emission control systems. Automotive engineers have told us that if they knew about such failures, automakers could without great difficulty identify the design or manufacturing practices that led to the flaw and correct the problem in future vehicles. If manufacturers did not take action, regulations could penalize them for models that display unacceptable rates of failure.

Why haven't stringent regulations on car emissions cut air pollution more?



With more durable emission control systems, cars would remain as clean as new for a far longer time—helping remove automobiles from their present status as the major source of air pollution. ■

MARC ROSS is a professor of physics at the University of Michigan. TOM WENZEL is a policy analyst at Lawrence Berkeley National Laboratory. They have been studying emissions from in-use vehicles for several years.

ILLUSTRATION: HENRIËTTE SCHERFT

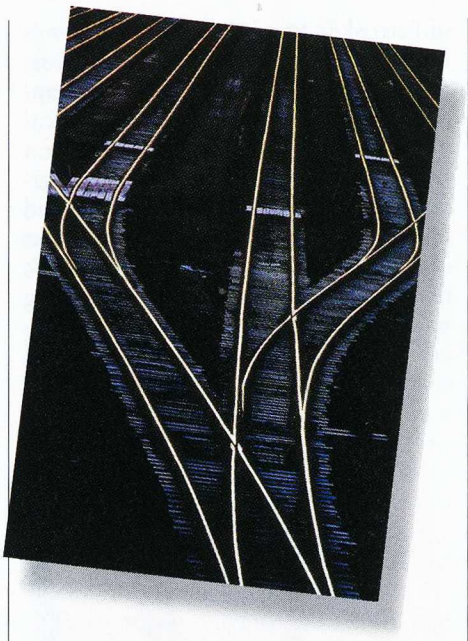
Reviews

BOOKS

A Journey More Important than Its Destination

Aramis, or the Love of Technology
by Bruno Latour
Harvard University Press, $19.95

BY NORMAN WEINSTEIN



Like Tracy Kidder's *The Soul of a New Machine*, French sociologist Bruno Latour's *Aramis, or the Love of Technology* is a literary hybrid: a non-fiction case study that uses fictional devices to show how a technological invention is brought to life. Where Kidder focused on the designers of a new Data General computer, Latour examines the various parties trying to build an automated train system in France.

Latour does not pursue this literary form to be fashionably avant-garde. He, unlike Kidder, is describing an invention that ostensibly failed despite an R&D phase that lasted nearly 20 years, from 1969 to 1987. To understand why this occurred, Latour includes the broadest spectrum of voices, including that of the train itself, which is called Aramis.

With the voices intentionally interrupting one another, the story sometimes might be difficult to follow, especially for the reader who enjoys conventionally linear tales. Just when the reader believes he or she is beginning to see why the complex computer system guiding the cars might work in real-world situations, a politician interrupts to explain why the transportation unions would never accept this "driverless" system. When Aramis occasionally pipes up with its own ideas about its identity, it sounds like a Greek chorus from another planet. Midway through the book, Aramis, whose words are italicized throughout (Latour uses various fonts to help readers track the voices in his tale), poignantly confronts its makers, "If I have been badly conceived, why not conceive me again. . . . Why do you turn your heads away?"

The story unfolds through the interplay of the book's two fictional characters, a sociology professor and a young engineering graduate student. As they interview the major players, the two joust over sociological theories that purport to explain the project's failure—and undergo dramatic personal turnabouts in the process. For example, the student initially wants and needs to believe that real-world technologies grow naturally out of scientifically sound principles. The professor, Norbert, who is portrayed as much a poet as a sociologist, knows, however, that "no technological project is technological first and foremost." Midway through his research, Norbert remarks, for example, that the various parties involved had engendered at least 15 different and competing definitions of Aramis. Transportation engineers began with one concept. Politicians imposed modifications. Finance ministers imposed design compromises based upon funding. And on and on. Even after the French government finally killed the project in 1987, various parties were still envisioning alternative transportation systems out of dismembered parts of Aramis.

In a sense, Norbert is a "talking head" for the book's author, who has spent his life clarifying how science and technology translate into real-world applications. Books like *Laboratory Life* (1986), cowritten by Steve Woolgar, and *Science in Action* (1987) carefully elucidate the impact of social contexts on scientific research. Through historical analysis, *The Pasteurization of France* (1988) showed how the technique's eventual success owed much to outside forces. *Interviews with Michel Serres on Science, Culture, and Time* (1990) found Latour rigorously interrogating the philosopher of science known for provocatively blurring boundaries between the sciences and humanities, a central characteristic of Latour's books. These earlier works set the stage for *Aramis* and its constantly shifting network of voices.

By framing the sociology of Aramis within a literary form, Latour has done more than create an entertaining "read" about technological endeavors. He has compelled his readers to shift perspective constantly so that they gain an appreciation of the complexity of forces at play behind technological inventions. "Look at that plot, my young friend," remarks Norbert to his student. "If it were a play by Corneille, people would call it a miracle; they'd admire the violence of the passions, the intensity of the reversals. Yet we're dealing with automated subway systems and technocrats. This is the real literature of our day."

After the student and his professor understand why Aramis never fulfilled its initial promise—and I won't spoil the fun by giving away their conclusion—the professor declares that he will write a book about Aramis. His student shrugs and asks what the point would be. "Well," Norbert responds, "it would be good for training people like you. And it would be good for educating the public, for getting people to

PHOTO: MASTERFILE/ROY OOMS

understand, getting them to love technologies. I'd like to turn the failure of Aramis into a success so it won't have died in vain."

If the word "love" seems a bit romantic when dissecting the fate of a public transportation system, part of Latour's genius is to make you care about the train as much as any person involved. The book's title hits home when the reader realizes that to love technology is to fall under the spell of all the human and nonhuman actors who create it.■

NORMAN WEINSTEIN is a poet and critic whose most recent book is A Night in Tunisia: Imaginings of Africa in Jazz *(Limelight Editions, 1992).*

BOOKS

THE ENGINEER'S MULTIFACETED WORLD

Invention by Design: How Engineers Get from Thought to Thing
by Henry Petroski
Harvard University Press, $24.95

BY SAMUEL C. FLORMAN

LET us begin with full disclosure: I admire Henry Petroski, and I'm predisposed to think well of just about anything he publishes. This is mainly due to the excellent books and engrossing articles he has written in the past. But it is also because we are members of a small community of engineers who write about engineering from a humanistic viewpoint—with the general reader in mind as well as fellow professionals. Through his prodigious example, Petroski has become this group's widely acclaimed leader.

It is hard to believe that only a dozen years have passed since the publication of Petroski's first book, *To Engineer Is Human: The Role of Failure in Successful Design*. This literary endeavor captured the fancy of the nontechnical world and provided the impetus for a BBC television special. *Beyond Engineering*, a potpourri of essays, followed in 1986. Then came three books that completely broke through the barriers that had so long separated engineering writing from popular culture: *The Pencil: A History of Design and Circumstance* (1990), *The Evolution of Useful*

Things (1992), and *Engineers of Dreams: Great Bridge Builders and the Spanning of America* (1995).

Granted, there are a number of talented people writing about technology today, more than there were just two or three decades ago. David McCullough's books about the Panama Canal and the Brooklyn Bridge are superb popular history, as are Richard Rhodes's works on the atomic and hydrogen bombs. Tracy Kidder's *The Soul of a New Machine* well deserved its Pulitzer Prize. But while this growing attention to the history of technology is heartening, none of these authors are practicing engineers.

Does it matter? Shouldn't we be satisfied if engineering is represented in the literary arena by professional writers, many of whom have had technical training? Although the answer is partially yes, in an important way it is no. Only a practicing engineer can "feel" what it is to do engineering and "know" engineering with heart and soul.

Petroski seeks to convey such intimacies in his latest work, *Invention by Design*, a deftly conceived textbook for college courses. Instead of taking his readers into the murky depths of technical definitions, as others have done, Petroski offers nine engineering undertakings, each one of which exemplifies a particular aspect of the engineering process. He begins with a brief history of the paper clip, through which he introduces the concept of design. A key source of design is discontent with an existing product. To illustrate this, Petroski focuses on the need in the late nineteenth century for a replacement for straight pins, which were then used to hold papers together. Eventually, the classic Gem clip, with which we are all familiar, became the standard for this task. Even though the clip is widely accepted and has often been praised for its grace and beauty, Petroski points out a half-dozen deficiencies, such as its inability to hold more than a few papers, and offers as evidence the many patent filings for new variations.

Next, Petroski uses the evolution of the pencil point to explain the process of engineering analysis. This seemingly simple object has been improved through study of its geometry, its material composition, and the methodology of its manufacture. Through this example, Petroski shows that engineers cannot rely solely on creative design plus pure mathematics, but must evaluate their ideas, taking into account the physical imperfections of substances and other contingencies of the material world.

Even conceptual ideas and analytical reviews, however, are not substitutes for the endless physical tinkering required to come up with a successful product. Nor can this process—development—be isolated from the financial and marketing

considerations inherent in engineering. Petroski illustrates how such business forces prompted engineers to invent and then reinvent the zipper, eventually leading to innovations such as Velcro, the plastic zipper, and the resealable plastic bag. Even readers who think they are familiar with this process will be amazed by the interactions among technical work, patent struggles, and competitive merchandising.

"Engineering has many dimensions," Petroski next writes, "but the idea of failure spreads across all of them." Engineers make progress by designing to preconceived limits and then learning from failure. He explains, for example, that engineers refined the aluminum can's structural shape with the aid of machines that test it to failure under pressure. Interestingly, the can's pop-top opener is designed to "fail in a controlled way"—to tear open conveniently but not to leak or break off in the hand.

The importance to engineered products of supporting infrastructures—"networks" is the author's term—is explained through the saga of the fax machine. This device was successfully designed long before it could be widely marketed, its utility to consumers limited by the signal-carrying capacity of telephone lines.

The computer's crucial role in engineering is illustrated in the chronicle of the Boeing 777. For that project, computer-aided design (CAD) was carried to new heights. A "paperless" design strategy meant that 238 teams, each as many as 40 engineers, could call up details at any of 7,000 linked workstations.

To show how engineering affects, and is affected by, social forces and politics, Petroski devotes two chapters to, respectively, water supply and bridge building. Here he ranges far and wide, discussing Roman aqueducts, Parisian sewers, the bridges of San Francisco, and other historically significant projects.

Finally, in considering the phenomenon of complex systems, he discusses the past, present, and possible future of the modern skyscraper—its structural designs, mechanical ingenuities, elevator networks, and relationship to the environment. He concludes by reflecting on the World Trade Center in New York City, whose two towers must accommodate 50,000 employees and 80,000 visitors daily. This load taxes not only technological systems within the towers but such community systems as transportation, mail, and telephone.

CONTINUED FROM PAGE 8

Petroski's mosaic approach provides a wonderfully comprehensive synthesis of what it is that engineers actually do. While he includes more diagrams, mathematics, and theoretical mechanics in this work than in his books for the general public, there is nothing here to intimidate the ordinary informed reader. He maintains a light touch that is sadly lacking in most works about engineering—certainly works intended for students. Happily, an encounter with any one of Petroski's books should lead readers to explore his others.■

SAMUEL C. FLORMAN, a civil engineer and a columnist for Technology Review, *is the author of* The Existential Pleasures of Engineering, *recently reissued in a new edition. His latest book is* The Introspective Engineer.

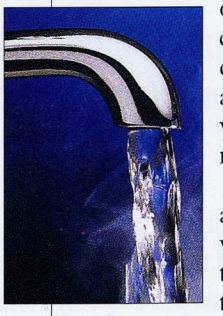
Is there any reason to believe that success in detecting bombs will not lead terrorists to use yet another device? Fischetti points out that the introduction of security devices to reveal the guns and knives led terrorists to switch to bombs. With successful bomb detection, terrorists may resort to chemical and biological weapons.

The only effective way I think we can attack terrorism is for our president to advocate retaliation to a degree commensurate with the terrorist attack we have suffered against the specific communities that support and spawn terrorism. Whereas terrorists have suffered only a few prosecutions and life sentences, hundreds of innocent Americans have lost their lives. Bomb detectors are unlikely to change that ratio.

BERNARD H. GEYER
Prescott, Ariz.

WADING THROUGH A SEA OF OPTIONS

I find it difficult to critique articles like Sarah Postel's "Dividing the Waters" (*TR April 1997*) without appearing Pollyannaish. Obviously, the global supply of water is limited and the demands placed upon the resource are growing rapidly. The situation should clearly not engender complacency. But should it elicit the author's panic?



This article, like the whole neo-Malthusian literature, essentially takes historical behavior and projects it into the future. Postel is firmly in the tradition of the Club of Rome's *Limits to Growth*, which forecast shortages of a range of natural resources, and of Jimmy Carter's Global 2000, which predicted that the world would run out of oil. Both these prognostications were wrong for precisely the same reasons that Postel's predictions will be wrong—they all ignore the ability of homo sapiens to change its behavior radically when it senses approaching catastrophe. Having noticed water is scarce in some places, we now must decide to act. Properly applying what we already know about irrigation technologies, water-conservation technologies, rain-fed agriculture, and urban and industrial recycling will enable us to coast comfortably through the next 30 years.

Specifically, I suggest sensible pricing mechanisms for water. As Postel notes, water is typically underpriced even in water-scarce areas, where governments subsidize water service, often in the name of protecting the small farmer or the poor householder. Most of the benefits, however, go to wealthy farmers and the urban rich.

Sensible pricing policies would have three effects. First, raising the price would lower demand. Second, a higher price would increase the supply by making otherwise expensive supply options more economically viable. Finally, higher prices would give water-management utilities more revenue to improve service to consumers. That, in turn, would increase the water's perceived value to consumers. Between the extremes of fully private water markets and fully government-controlled utilities are a wide range of economic tools that can achieve sensible and realistic pricing.

We can also reduce the huge amounts of water now used for agriculture. A 10 percent reduction would make available ample amounts of water to meet growing demand from other users.

Postel's article provides a pessimistic view of the water crisis. One has only to look at the options to feel confident that we can solve the water crisis remarkably straightforwardly.

PETER ROGERS
Director of Applied Sciences
Harvard University
Cambridge, Mass.

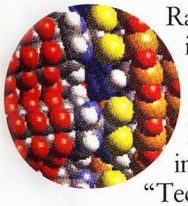
AN IDEA WHOSE TIME HAS COME—AGAIN

In "Kosher Sound" (*Trends, TR February/March 1997*), Stephen Strauss examines a kosher public-address system powered by compressed air rather than electricity, whose use on the Sabbath and other holy days is forbidden by Jewish law. The article reminded me

that there is nothing new under the sun. While indulging my hobby of aeronautical history, I once read about Horace Short, who in 1898 invented the auxetophone, a loudspeaker powered by either steam or compressed air. Although Short's invention was not as sophisticated as Strauss's, it was able to broadcast pre-recorded arias in 1900 from the top of the Eiffel Tower loud enough to be heard throughout Paris.

WESLEY F. MOORE
Seattle, Wash.

NOT A SMALL MATTER



In "It's a Small, Small, Small, Small World" *(TR February/March 1997)*, Ralph C. Merkle cites my opinion on nanotechnology by using a quote from *Scientific American*. Readers would be better served by referencing the quote's original source, "Technological Boundless Optimism" (*Nature, April 27, 1995*).

DAVID JONES
Professor of Chemistry
University of Newcastle
Newcastle upon Tyne, England

NO TIME LIKE THE PRESENT

In "Waiting for Uncle Bill" (*Phenomena, TR April 1997*), David Brittan writes, "Let us hope that [Bill] Gates makes up his mind [about becoming a philanthropist] in this lifetime." We should also heed Mother Teresa's remarks to me in an interview that giving is sharing, which has nothing to do with the volume of one's wealth.

KAMAKSHI BALASUBRAMANIAN
Ibadan, Nigeria

AMPLIFICATION

The photograph illustrating "Arsenic and Old Waste" (*Trends, TR May/June 1997*) neglected to identify Peter J. Zeeb, who was a graduate student in MIT's Department of Civil and Environmental Engineering when the image was taken. Zeeb developed the instrument shown in the photo to observe changes in oil properties and thus understand the movement of arsenic in the environment.

Classifieds

InSight

TODAY'S TEST TUBES

Picture that icon of science, the test tube. Now forget it—or at least envision it as a vastly smaller and differently shaped vessel that is leading to a much faster, more organized, and less expensive way to develop drugs, agrichemicals, and advanced materials.

The square-inch grid shown here contains 128 troughs—new-wave test tubes—filled with varying combinations of metallic oxides that scientists examined for their ability to form high-temperature superconductors. A research team at the Lawrence Berkeley National Laboratory, led by physicist Xiao-Dong Xiang and chemist Peter Schultz, used a gun-like mechanism to deposit the chemicals. After applying heat to mix and stabilize them, the scientists lowered a plate with 128 probes to test which compounds showed negligible electrical resistance at certain temperatures—an indication of potential superconductivity.

In a process known as combinatorial chemistry, scientists are using such grids to assemble and evaluate large numbers of permutations of compounds at one time. To continue their research, for example, Xiang and his colleagues created one-inch grids with 1,024 troughs earlier this year.

This photograph, which shows molecular combinations diffracting light like paints in a miniature watercolor palette, was taken by Felice Frankel, artist-in-residence at MIT's Edgerton Center. Her forthcoming book *On the Surface of Things* (Chronicle Books, 1997) will include a similar image, among many other photographs, and text by George Whitesides, a Harvard University professor of chemistry.

—*Mark Dwortzan*

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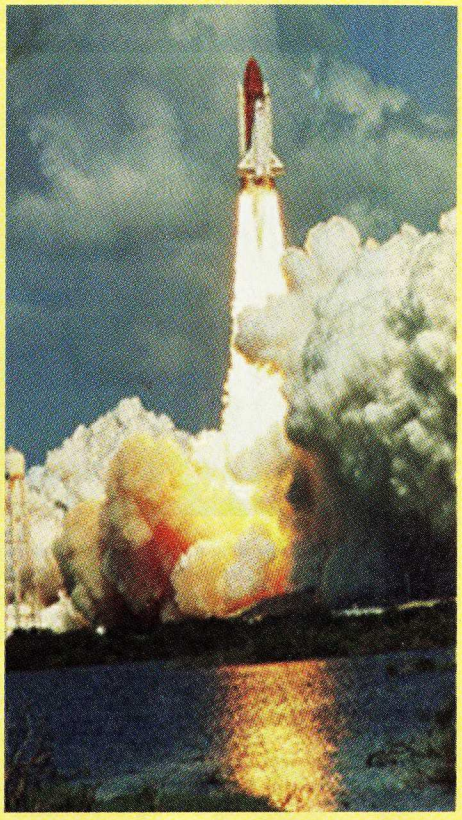

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Merrill Lynch • AT&T Resource Link • Prodigy • Lockheed Martin M&DS • Perot Systems • Dow Jones & Co. • Big Apple Technologies • ITT Avionics • ACR • Advanced Computing Techniques • AE Feldman & Associates • Aegis Software • AFS & LSC Services • Cap Gemini • Unixpros • Chubb Computer Services • Computer Aid • Computer Consultants & Contractors Newsletter • Context Integration • CP Interactive • CW Costello & Associates • DIS Research • DMR Trecom • Chubb & Son • Dux International/Kenda Systems • EDS • Gartner Group • Grace Technologies • Hobart Information Technology • Holden Partners • Howard Systems Int'l • IMI Systems • Integrated Systems Consulting • Intersolv • LANcomp • LinkPoint • TSC • Ajilon • Logical Design Solutions • Beechwood Data Systems • Logistic Solutions • Manpower Technical • McIntyre Information Technology • Nesco Information Systems • Noblestar Systems • Paragon Computer Professionals Inc. • PC Etc. • PLP/Professional Partners • Productivity Point Int'l. • Realtech Systems Corporation • RHI Consulting • RMS Computer • Origin Technology Corp. • Rohn Rogers Associates • Royal Blue Technologies • Setford Shaw Najarian • Simulate • Source EDP/Consulting • Spectrum Technology Group • Staffworks • Summit Bank • Telos Corporation • Keane • Approach • The A Consulting Team./TACT • Tiffany Computer Systems • Tiger Information Systems • Arcus Data Staffing • ***and many more.***

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If you cant attend please send your resume to JOBEXPO MIT 36 East 23rd Street 8th Flr, NY, NY 10010 **Companies interested in exhibiting call (212) 505-1780**

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DIGITAL SIGNAL PROCESSING

DSP SOFTWARE DEVELOPMENT ENGINEERS

Develop DSP Software tool for Reconfigurable Computing Systems. Responsibilities include architecture, design, implementation, test and demoing of development systems, including interfacing with hardware engineers, using C++, DSP/FPGA development tools and OOA/OOD techniques.

DSP SOFTWARE DEVELOPMENT ENGINEERS-ALGORITHM

Develop, implement and integrate communications DSP Algorithms. Experience in signal demodulation, recognition and synthesis using DSP techniques is desirable. Voice and data signal analysis in HF, VHF, and UHF signal environments as well as knowledge of advanced modem techniques, spread spectrum and detection theory are a plus. Software skills required; MATLAB, UNIX and real-time processing with C, Ada and TM320 Assembly.

DSP HARDWARE RAPID DEVELOPMENT EXPERT

Rapid prototyping of high-performance DSP hardware modules and systems. Prototype embedded electronic systems that range from underwater acoustic modems to synthetic aperture RADAR image formation processors. Requires theoretical and applied expertise in emerging hardware technologies in mathematical computing with FPGAs and in high-speed, high-density and very low power designs.

DSP ALGORITHM AND PROTOTYPE DESIGN

Design and implement signal processing systems including custom hardware and software designs together with efficient algorithm implementation. Experience with designs using DSP chips and implementation of signal processing functions using FPGAs.

ELECTRICAL ENGINEERING

ADVANCED PACKAGING

Design and analysis of high-density single chip and thick/thin film multichip module (MCM) packaging solutions. Signal integrity analysis experience desired.

ANALOG-TO-DIGITAL CONVERSION

Requires significant experience in high-speed (>50 MHz), high-resolution (>8 bits), A/D and D/A conversion.

ADAPTIVE COMPUTING

FPGA-based adaptive computing technical lead. Experience in FPGA design and advanced computer architectures. CAE tool development experience desired.

SOFTWARE

UNIX NETWORKING EXPERT

Real-time DSP applications. UNIX, real-time systems (Lynos/VxWorks) networking technologies (FDDI/ATM...) NW systems architectures.

SOFTWARE RAPID PROTOTYPING EXPERT

Rapid prototyping of real-time or distributed interactive computing systems. Prototype systems that range from signal processing for the battlefield to mapping, charting and imagery-systems for space vehicles. Requires theoretical and applied expertise in emerging computer science in operating systems, languages, tools, network distributed computing parallel processing, and networkings.

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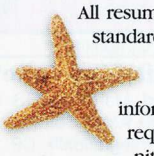
Fax: (603) 885-6398. EMAIL: hrrep@mailgw.sanders.com



All resumes are scanned and we request that you please use standard format and fonts. Applicants selected may be subject to a government security investigation and must meet eligibility requirements for access to classified information. Due to ITAR restrictions, US citizenship required for most positions. Sanders is an equal opportunity/ affirmative action employer.

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